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भारतीय मानक

विस्फोटी पर्यावरण

भाग 7 बढ़ी सुरक्षा "e" द्वारा उपकरण संरक्षण

Indian Standard

EXPLOSIVE ATMOSPHERES

PART 7 EQUIPMENT PROTECTION BY INCREASED SAFETY "e"

ICS 29.260.20

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

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Electrical Apparatus for Explosive Atmospheres Sectional Committee, ETD 22

NATIONAL FOREWORD

This Indian Standard (Part 7) which is identical with IEC 60079-7 : 2006 'Explosive atmospheres — Part 7: Equipment protection by increased safety "e" ' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Electrical Apparatus for Explosive Atmospheres Sectional Committee and approval of the Electrotechnical Division Council.

This standard supersedes IS 6381 : 2004 'Electrical apparatus for explosive gas atmospheres — Increased safety "e" (*first revision*)'. IS 6381 : 2004 would continue for certification till such a time IS/IEC 60079-7 : 2006 is implemented.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, references appear to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards, which are to be substituted in their respective places, are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60034-1 Rotating electrical machines — Part 1: Rating and performance	IS 325 : 1996 Three-phase induction motors (*first revision*)	Technically Equivalent
IEC 60034-5 Rotating electrical machines — Part 5: Degrees of protection provided by the internal design of rotating electrical machines (IP code) — Classification	IS 4691 : 1985 Degrees of protection provided by enclosure for rotating electrical machinery (*first revision*)	do
IEC 60050 (426) : 1990 International electrotechnical vocabulary — Chapter 426: Electrical apparatus for explosive atmospheres	IS 1885 (Part 60) : 1993 Electrotechnical vocabulary: Part 60 Electrical apparatus for explosive atmospheres (*first revision*)	Identical
IEC 60061-1 Lamp caps and holders together with gauges for the control of interchangeability and safety — Part 1: Lamp caps	IS 2418 (Part 3) : 1977 Tubular fluorescent lamps for general lighting service: Part 3 Dimensions of G-5 and G-13 bi-pin caps (*first revision*)	Technically Equivalent
	IS 9206 : 1979 Dimensions of caps for tungsten filament general service electric lamps	do

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60061-2 Lamp caps and holders together with gauges for the control of interchangeability and safety — Part 2: Lampholders	IS 2418 (Part 4) : 1977 Tubular fluorescent lamps for general lighting service: Part 4 Go and no-go gauges for G-5 and G-13 bi-pin caps (*first revision*)	Technically Equivalent
IEC 60064 Tungsten filament lamps for domestic and similar general lighting purposes — Performance requirements	IS 418 : 2004 Tungsten filament lamps for domestic and similar general lighting purposes (*fourth revision*)	do
IEC 60068-2-6 Environmental testing — Part 2: Tests — Test Fc: Vibration (sinusoidal)	IS 9000 (Part 8) : 1981 Basic environmental testing procedures for electronic and electrical items: Part 8 Vibration (sinusoidal) test	do
IEC 60068-2-27 : 1987 Environmental testing — Part 2: Tests — Test Ea and guidance: Shock	IS 9000 (Part 7/Sec 1) : 1979 Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Section 1 Shock (Test Ea)	do
IEC 60068-2-42 Environmental testing — Part 2: Tests — Test Kc: Sulphur dioxide test for contacts and connections	IS 9000 (Part 26) : 1980 Basic environmental testing procedures for electronic and electrical items: Part 26 Sulphur dioxide test for contacts and connections	do
IEC 60079-0 : 2004 Electrical apparatus for explosive gas atmospheres — Part 0: General requirements	IS/IEC 60079-0 : 2004 Electrical apparatus for explosive gas atmospheres: Part 0 General requirements	Identical
IEC 60079-1 : 2007 Electrical apparatus for explosive gas atmospheres — Part 1: Flameproof enclosures "d"	IS/IEC 60079-1 : 2007 Electrical apparatus for explosive gas atmospheres: Part 1 Flameproof enclosures "d"	do
IEC 60079-11 : 2006 Explosive atmospheres — Part 11: Equipment protection by intrinsic safety "i"	IS/IEC 60079-11 : 2006 Explosive atmospheres: Part 11 Equipment protection by intrinsic safety "i"	do
IEC 60085 Electrical insulation — Thermal classification	IS 1271 : 1985 Thermal evaluation and classification of electrical insulation (*first revision*)	Technically Equivalent
IEC 60112 Method for the determination of the proof and the comparative tracking indices of solid insulating materials	IS 2824 : 1975 Method for determining the comparative tracking index of solid insulating materials under moist conditions (*first revision*)	do
IEC 60228 Conductors of insulated cables	IS 8130 : 1984 Conductors for insulated electric cables and flexible cords (*first revision*)	do
IEC 60238 Edison screw lampholders	IS 10276 : 1982 Edison screw lampholders: Part 1 Requirements and tests Part 2 Standard data sheets for lampholders and gauges	do

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60317-3 : 2004[1] Specifications for particular types of winding wires — Part 3: Polyester enamelled round copper wires, class 155	IS 13730 (Part 3) : 1996 Specifications for particular types of winding wires: Part 3 Polyester enamelled round copper wires, class 155	Technically Equivalent
IEC 60317-7 : 1990 Specifications for particular types of winding wires — Part 7: Polyimide enamelled round copper wire, class 220	IS 13730 (Part 7) : 1993 Specifications for particular types of winding wires: Part 7 Polyimide enamelled round copper wire, class 220	Identical
IEC 60317-8 : 1990 Specifications for particular types of winding wires — Part 8: Polyesterimide enamelled round copper wire, class 180	IS 13730 (Part 8) : 1993 Specifications for particular types of winding wires: Part 8 Polyesterimide enamelled round copper wire, class 180	do
IEC 60317-13 : 1990 Specifications for particular types of winding wires — Part 13: Polyester or polyesterimide overcoated with polyamide-imide enamelled round copper wire, class 200	IS 13730 (Part 13) : 1993 Specifications for particular types of winding wires: Part 13 Polyester or polyesterimide overcoated with polyamide-imide enamelled round copper wire, class 200	do
IEC 60400 Lampholders for tubular fluorescent lamps and starterholders	IS 3323 : 1980 Bi-pin lampholders for tubular fluorescent lamps (*first revision*)	Technically Equivalent
	IS 3324 : 1982 Holders for starters for tubular fluorescent lamps (*first revision*)	do
IEC 60432-1 Incandescent lamps — Safety specifications — Part 1: Tungsten filament lamps for domestic and similar general lighting purposes	IS 15518 (Part 1) : 2004 Safety requirements for incandescent lamps: Part 1 Tungsten filament lamps for domestic and similar general lighting purposes	do
IEC 60529 Degrees of protection provided by enclosures (IP Code)	IS 12063 : 1987 Classification of degrees of protection provided by enclosures of electrical equipment	do
IEC 60664-1 : 1992[2] Insulation coordination for equipment within low-voltage systems — Part 1: Principles, requirements and tests	IS 15382 (Part 1) : 2003 Insulation coordination for equipment within low-voltage systems: Part 1 Principles, requirements and tests	do
IEC 60947-1 : 1988 Low-voltage switchgear and controlgear — Part 1: General rules	IS 13947 (Part 1) : 1993 Specification for low-voltage switchgear and controlgear: Part 1 General rules	Identical
IEC 61347-2-3 : 2000 Lamp controlgear — Part 2-3: Particular requirements for ac supplied electronic ballasts for fluorescent lamps	IS 13021 (Part 2) : 1991 ac supplied electronic ballasts for tubular fluorescent lamps — Specification: Part 2 Performance requirements	Technically Equivalent
IEC 62086-1 Electrical apparatus for explosive gas atmospheres — Electrical resistance trace heating — Part 1: General and testing requirements	IS 14774 (Part 1) : 2000 Electrical resistance trace heating in potentially explosive atmospheres: Part 1 General and testing requirements	do

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[1] Corresponding Indian Standard is identical to IEC 60317-3 : 1990.

[2] Since revised in 2002.

The technical committee has reviewed the provisions of the following International Standards referred in this adopted standard and has decided that they are acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60044-6	Instrument transformers — Part 6: Requirements for protective current transformers for transient performance
IEC 60364-3	Electrical installations of buildings — Part 5-55: Selection and erection of electrical equipment — Other equipment
IEC 60947-7-1	Low-voltage switchgear and controlgear — Part 7: Ancillary equipment — Section 1: Terminal blocks for copper conductors
IEC 60947-7-2	Low-voltage switchgear and controlgear — Part 7: Ancillary equipment — Section 2: Protective conductor terminal blocks for copper conductors
IEC 60999-1	Connecting devices — Electrical copper conductors — Safety requirements for screw-type and screwless-type clamping units — Part 1: General requirements and particular requirements for clamping units for conductors from 0.2 mm^2 up to 35 mm^2 (included)
IEC 60999-2	Connecting devices — Electrical copper conductors — Safety requirements for screw-type and screwless-type clamping units — Part 2: Particular requirements for clamping units for conductors above 35 mm^2 up to 300 mm^2 (included)
IEC 61195 : 1999	Double-capped fluorescent lamps — Safety specifications
ISO 2859-1 : 1999	Sampling procedures for inspection by attributes — Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection

Only the English language text of the International Standard has been retained while adopting it in this Indian Standard, and as such the page numbers given here are not the same as in the IEC Standard.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

EXPLOSIVE ATMOSPHERES

PART 7 EQUIPMENT PROTECTION BY INCREASED SAFETY "e"

1 Scope

This part of IEC 60079 specifies the requirements for the design, construction, testing and marking of electrical apparatus with type of protection increased safety "e" intended for use in explosive gas atmospheres. This standard applies to electrical apparatus where the rated voltage does not exceed 11 kV r.m.s. a.c. or d.c. Additional measures are applied to ensure that the apparatus does not produce arcs, sparks, or excessive temperatures in normal operation or under specified abnormal conditions.

This standard supplements and modifies the general requirements of IEC 60079-0. Where a requirement of this standard conflicts with a requirement of IEC 60079-0, the requirement of this standard takes precedence.

NOTE Increased safety "e" can provide Equipment Protection Levels (EPL) Mb or Gb. For further information, see Annex I.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-5, *Rotating electrical machines – Part 5: Degrees of protection provided by the internal design of rotating electrical machines (IP code) – Classification*

IEC 60044-6, *Instrument transformers – Part 6: Requirements for protective current transformers for transient performance*

IEC 60050(426), *International Electrotechnical Vocabulary (IEV) – Chapter 426: Electrical apparatus for explosive atmospheres*

IEC 60061-1, *Lamp caps and holders together with gauges for the control of interchangeability and safety – Part 1: Lamp caps*

IEC 60061-2, *Lamp caps and holders together with gauges for the control of interchangeability and safety – Part 2: Lampholders*

IEC 60064, *Tungsten filament lamps for domestic and similar general lighting purposes – Performance requirements*

IEC 60068-2-6, *Environmental testing – Part 2: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-27:1987, *Environmental testing – Part 2: Tests – Test Ea and guidance: Shock*

IEC 60068-2-42, *Environmental testing – Part 2-42: Tests – Test Kc: Sulphur dioxide test for contacts and connections*

IEC 60079-0:2004, *Electrical apparatus for explosive gas atmospheres – Part 0: General requirements*

IEC 60079-1, *Electrical apparatus for explosive gas atmospheres – Part 1: Flameproof enclosures "d"*

IEC 60079-11, *Electrical apparatus for explosive gas atmospheres – Part 11: Equipment protection by intrinsic safety "i"*

IEC 60085, *Electrical insulation – Thermal classification*

IEC 60112, *Method for the determination of the proof and the comparative tracking indices of solid insulating materials*

IEC 60228, *Conductors of insulated cables*

IEC 60238, *Edison screw lampholders*

IEC 60317-3:2004, *Specifications for particular types of winding wires – Part 3: Polyester enamelled round copper wires, class 155*

IEC 60317-7:1990, *Specifications for particular types of winding wires – Part 7: Polyimide enamelled round copper wire, class 220*

IEC 60317-8:1990, *Specifications for particular types of winding wires – Part 8: Polyesterimide enamelled round copper wire, class 180*

IEC 60317-13:1990, *Specifications for particular types of winding wires – Part 13: Polyester or polyesterimide overcoated with polyamide-imide enamelled round copper wire, class 200*

IEC 60364-3, *Electrical installations of buildings – Part 5-55: Selection and erection of electrical equipment – Other equipment*

IEC 60400, *Lampholders for tubular fluorescent lamps and starterholders*

IEC 60432-1, *Incandescent lamps – Safety specifications – Part 1: Tungsten filament lamps for domestic and similar general lighting purposes*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1:1992, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements, and tests*

IEC 60947-1, *Low-voltage switchgear and controlgear – Part 1: General rules*

IEC 60947-7-1, *Low-voltage switchgear and controlgear – Part 7: Ancillary equipment – Section 1: Terminal blocks for copper conductors*

IEC 60947-7-2, *Low-voltage switchgear and controlgear – Part 2 – Ancillary equipment – Section 1: Protective conductor terminal blocks for copper conductors*

IEC 60999-1, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 1: General requirements and particular requirements for clamping units for conductors from 0,2 mm^2 up to 35 mm^2 (included)*

IEC 60999-2, *Connecting devices – Electrical copper conductors – Safety requirements for screw-type and screwless-type clamping units – Part 2: Particular requirements for clamping units for conductors above 35 mm^2 up to 300 mm^2 (included)*

IEC 61195:1999, *Double-capped flucrescent lamps – Safety specifications*

IEC 61347-2-3:2000, *Lamp controlgear – Part 2-3: Particular requirements for a.c. supplied electronic ballasts for fluorescent lamps*
Amendment 1(2004)
Amendment 2 (2006)

IEC 62086-1, *Electrical apparatus for explosive gas atmospheres – Electrical resistance trace heating – Part 1: General and testing requirements*

ISO 2859-1, *Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

3 Terms and definitions

For the purposes of this document, the terms and definitions used in IEC 60079-0, together with the following terms and definitions apply.

For the definitions of any other terms, particularly those of a more general nature, reference should be made to IEC 60050(426) or other appropriate parts of the IEV (International Electrotechnical Vocabulary).

3.1
clearance
shortest distance in air between two conductive parts

3.2
connections, factory
terminations intended for connection during a manufacturing process under controlled conditions

3.3
connections, field-wiring
terminations intended for connection by the installer in the field

3.4
creepage distance
shortest distance along the surface of an electrically insulating material between two conductive parts

3.5
increased safety "e"
type of protection applied to electrical apparatus in which additional measures are applied so as to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks in normal service or under specified abnormal conditions

NOTE 1 This type of protection is denoted by "e". The "additional measures" are those required for compliance with this standard.

NOTE 2 Apparatus producing arcs or sparks in normal service is excluded by this definition of increased safety.

3.6
initial starting current
I_A
highest r.m.s. value of current absorbed by an a.c. motor when at rest or by an a.c. magnet with its armature clamped in the position of maximum air gap when supplied at rated voltage and rated frequency

NOTE Transient phenomena are ignored.

3.7
limiting temperature
maximum permissible temperature for apparatus or parts of apparatus equal to the lower of the two temperatures determined by

a) the danger of ignition of the explosive gas atmosphere,

b) the thermal stability of the materials used

NOTE This temperature may be the maximum surface temperature (see both 3.18 and Clause 5 of IEC 60079-0) or a lower value (see 4.7).

3.8
normal service, motors
continuous operation at the nameplate rating (or set of ratings) including starting conditions

3.9
rated dynamic current
I_{dyn}
peak value of the current, the dynamic effect of which the electrical apparatus can sustain without damage

3.10
rated short-time thermal current
I_{th}
r.m.s. value of the current required to heat up the conductor within 1 s from the temperature reached in rated service at the maximum ambient temperature to a temperature not exceeding the limiting temperature

3.11
rated voltage
value of voltage assigned by the manufacturer to a component, device or equipment and to which operation and performance characteristics are referred

3.12
resistance-heating devices and resistance-heating units

3.12.1
resistance-heating device
part of a resistance heating unit comprising one or more heating resistors, typically composed of metallic conductors or an electrically conductive material suitably insulated and protected

3.12.2
resistance-heating unit
apparatus comprising an assembly of one or more resistance heating devices associated with any devices necessary to ensure that the limiting temperature is not exceeded

NOTE It is not intended that the devices necessary to ensure that the limiting temperature is not exceeded should have type of protection "e", or any type of protection when they are located outside the hazardous area

3.12.3
workpiece
object to which a resistance-heating device or unit is applied

3.12.4
temperature self-limiting characteristic
characteristic whereby the thermal output of a resistance-heating device at its rated voltage decreases as the temperature of its surroundings increases until the device reaches a temperature at which its thermal output is reduced to a value at which there is no further rise in temperature

NOTE The temperature of the surface of the element is then effectively that of its surroundings

3.12.5
stabilized design
concept where the temperature of the resistance-heating device or unit will, by design and use, stabilize below the limiting temperature, under the most unfavourable conditions, without the need for a safety device to limit the temperature

3.13
short-circuit current
I_{sc}
maximum r.m.s. value of the short-circuit current to which the apparatus may be subjected in service

NOTE This maximum value is recorded in the documentation according to Clause 24 of IEC 60079-0

3.14
starting current ratio
I_A/I_N
ratio between initial starting current I_A and rated current I_N

3.15
time
t_E
time, in seconds, taken for an a.c. rotor or stator winding, when carrying the initial starting current I_A, to be heated up to the limiting temperature from the temperature reached in rated service at the maximum ambient temperature (see Figure A.1)

3.16
trace heater
device designed for the purpose of producing heat on the principle of electrical resistance and typically composed of one or more metallic conductors or an electrically conductive material suitably electrically insulated and protected

3.17
working voltage
highest r.m.s. value of the a.c. or d.c. voltage across any particular insulation which can occur when the equipment is supplied at rated voltage

NOTE 1 Transients are disregarded.

NOTE 2 Both open-circuit conditions and normal operating conditions are taken into account.

4 Constructional requirements for all electrical apparatus

4.1 General

The requirements of this clause apply, unless otherwise stated in Clause 5, to all electrical apparatus with type of protection "e" and are themselves supplemented for certain electrical apparatus by the supplementary requirements in Clause 5.

4.2 Electrical connections

4.2.1 General

Electrical connections are sub-divided into those for field-wiring and for factory wiring and into permanent types and re-connectable / re-wirable types for convenience in detailing the appropriate requirements.

Each type shall, as applicable:

a) be constructed in such a way that the conductors cannot slip out from their intended location during tightening of a screw or after insertion;

b) provide a means to avoid loosening of the connection in service;

c) be such that contact is assured without damage to the conductors such that would impair the ability of the conductors to fulfil their function, even if multi-stranded conductors are used in connections intended for direct clamping of a single conductor;

d) provide a positive compression force to assure contact pressure in service;

e) be constructed in such a way that the contact they assure is not appreciably impaired by temperature changes occurring in normal service;

f) except as permitted by the earth continuity test of IEC 60079-0, provide contact pressure that is not applied through insulating materials;

g) not be specified to accommodate more than one individual conductor in a clamping point unless specifically designed and assessed for doing so;

h) if intended for stranded conductors, employ a means to protect the conductors and distribute the contact pressure evenly. The method of applying contact pressure shall be capable, on installation, of reliably forming the stranded conductor into an effectively solid shape that does not subsequently change in service. Alternatively, the method of applying the contact pressure should be such that it is designed to accommodate any settlement of the strands in service;

i) for screw connections, have a specified torque value;

j) for screwless connections intended for class 5 and/or class 6 fine-stranded conductors according to IEC 60228, the fine-stranded wire shall be equipped with a ferrule or the termination shall have a method to open the clamping mechanism so that the conductors are not damaged during the installation of the conductor.

NOTE 1 The use of aluminium wire may cause difficulties by compromising critical creepage and clearance distances when anti-oxidant materials are applied. The connection of aluminium wire to terminals may be accomplished by the use of suitable bi-metallic connection devices providing a copper connection to the terminal.

NOTE 2 Special precautions against vibration and mechanical shock may be required.

NOTE 3 Special precautions against electrolytic corrosion should be considered.

NOTE 4 Special precautions against corrosion should be considered where ferrous materials are used.

NOTE 5 The limiting temperature of the insulation of terminal blocks and accessories will usually be based on the limiting temperature of the insulation in accordance with item a) of 4.7.2 but the limiting temperature allocated to the terminal when used in equipment will also depend on the maximum cable insulation temperature rating of the cable which is to be connected.

4.2.2 Field wiring connections

4.2.2.1 General

Terminals for field wiring shall be generously dimensioned to permit the effective connection of conductors of cross-section equal to at least that corresponding to the rated current of the electrical apparatus.

Connections shall be located in a position such that where required to be inspected in service they are reasonably accessible.

The number and size of conductors that can be safely connected shall be specified in the descriptive documentation according to IEC 60079-0.

4.2.2.2 Connections made using terminals complying with IEC 60947-7-1, IEC 60947-7-2, IEC 60999-1, or IEC 60999-2

Such terminals are intended for the connection of copper conductors with the insulation locally removed and without the addition of intermediate parts other than those replicating the form of a bare conductor, such as a ferrule.

Terminals shall be subject to the terminal insulation material tests of 6.9.

Terminals shall be capable of being fixed in their mountings.

The temperature rise of the conductor bar shall not exceed 45 K at a test current of 110 % of rated current according to the method of the temperature-rise test of IEC 60947-7-1.

NOTE 1 This test relates to the absolute maximum current rating of the terminal when tested without any enclosure. For practical purposes, when terminals are used in multiple within enclosures, it will be necessary to establish reduced current ratings according to the particular circumstances. See 5.8, 6.7 and Annex E.

Terminals for connecting conductors of rated cross-section not exceeding 4 mm^2 (12 AWG) shall also be suitable for the effective connection of conductors at least two ISO wire sizes smaller if not otherwise specified in the certificate. See Annex F.

NOTE 2 Subclause 4.2.2.2 is primarily intended to give requirements for terminals as components. When mounted in equipment any consequent limitations given in this standard apply.

4.2.2.3 Field wiring connection facilities integral to "e" apparatus or components

Terminals shall meet the requirements of 4.2.2.2, where applicable.

Temperatures for the verification of the thermal stability of materials shall be determined using a test sample configured to represent the complete apparatus, from a heating perspective, in accordance with IEC 60079-0.

4.2.2.4 Connections designed to be used with cable lugs and similar devices

Such connections shall be fixed in their mountings.

A means of securing the cable to prevent rotation or movement shall be provided to avoid either loosening or compromising creepage and clearance. Alternatively, it shall be demonstrated that such rotation or movement is not reasonably foreseeable.

4.2.2.5 Connections using permanent arrangements

These connections are typically tails with crimping or soldering facilities that are intended to be connected during installation using appropriate connection methods.

Either a means of fixing the completed connections to a suitable location is to be provided or the completed connections are to be provided with means of reliably insulating them to the requirements of this standard.

If the method of connection is by soldering, a method of providing mechanical support of the completed connection shall be provided. The security of the joint shall not be permitted to rely solely on the solder.

4.2.3 Factory connections

4.2.3.1 General

Factory connections shall be either fixed in a specific location or be provided with means of meeting the creepage and clearance requirements of this standard.

4.2.3.2 Field wiring connection methods used for factory connections

Any of the connection methods suitable for use as field wiring connections may be used for a factory connection, except in this case, the terminal insulation material tests of 6.9 need not be conducted.

4.2.3.3 Permanent connections

Permanent connections shall only be made by

a) crimping,

b) brazing,

c) welding,

d) soldering, provided that the conductors are not supported by the soldered connection alone.

4.2.3.4 Pluggable connections

These connections are designed to be readily connected or disconnected during assembly, maintenance, or repair.

NOTE Typical examples are plug-in components, and card edge connectors.

Pluggable connections shall provide the following:

a) each connection shall employ at least two contact arrangements where the effectiveness of each is substantially independent of the other;

b) each connection or group of connections shall be provided with a mechanical retaining device, which, excluding internal friction, provides a force resisting separation of at least 30 N. Where a group of individual connections is mechanically linked and the separable component weighs more than 0,25 kg or carries more than 10 cables, special consideration shall be given to the security of the connection;

c) for a lightweight connecting component relying on friction to remain in place and not attached in any way outside of the connection points, the separating force in Newtons shall be greater than 200 times the weight of the component and a mechanical retaining device is not required. The force shall be applied gradually near the centre of the component;

d) if the factory connection may remain energised when separated, it shall be provided with an interlock to prevent separation when energised or shall be marked in accordance with item b) of Table 12. For small items, adjacent marking can be provided.

4.2.3.5 Terminal bridging connections

These connections are designed to be made one-time only and not connected or disconnected during maintenance or repair.

A terminal bridging connection shall have a separating force in Newtons that is greater than 200 times the weight of the component. The force shall be applied gradually near the centre of the component.

4.3 Clearances

Clearances between bare conductive parts at different potentials shall be as given in Table 1 with a minimum value for external connections of 3 mm.

Spacings at wiring terminals shall be evaluated with the conductor size that produces the minimum clearance.

NOTE For requirements for lamps with screw caps, see 5.3.3.1.

Clearances shall be determined as a function of the working voltage. Where the apparatus is intended for more than one rated voltage or for a range of rated voltage, the value of working voltage to be used shall be based on the highest value of rated voltage. In determining the clearances, examples 1 to 11 (inclusive) in Figure 1 illustrate the features to be taken into account and the appropriate clearances.

Table 1 – Creepage distances and clearances

Voltage (see Note 1) $U_{r.m.s.}$ a.c. or d.c. V	**Minimum creepage distance** mm **Material group**			**Minimum clearance** mm
	I	II	IIIa	
10 (see Note 3)	1,6	1,6	1,6	1,6
12,5	1,6	1,6	1,6	1,6
16	1,6	1,6	1,6	1,6
20	1,6	1,6	1,6	1,6
25	1,7	1,7	1,7	1,7
32	1,8	1,8	1,8	1,8
40	1,9	2,4	3,0	1,9
50	2,1	2,6	3,4	2,1
63	2,1	2,6	3,4	2,1
80	2,2	2,8	3,6	2,2
100	2,4	3,0	3,8	2,4
125	2,5	3,2	4,0	2,5
160	3,2	4,0	5,0	3,2
200	4,0	5,0	6,3	4,0
250	5,0	6,3	8,0	5,0
320	6,3	8,0	10,0	6,0
400	8,0	10,0	12,5	6,0
500	10	12,5	16	8,0
630	12	16	20	10
800	16	20	25	12
1 000	20	25	32	14
1 250	22	26	32	18
1600	23	27	32	20
2 000	25	28	32	23
2 500	32	36	40	29
3 200	40	45	50	36
4 000	50	56	63	44
5 000	63	71	80	50
6 300	80	90	100	60
8 000	100	110	125	80
10 000	125	140	160	100

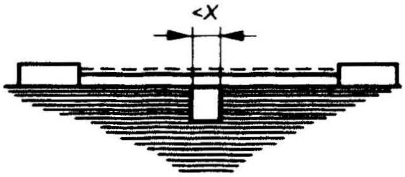
NOTE 1 Voltages shown are derived from IEC 60664-1 and are based on the rationalization of supply voltages given in Table 3b of IEC 60664-1. When determining the required values for creepage and clearance, the voltage value in the table may be increased by a factor of 1,1 in order to recognize the range of rated voltages in common use.

NOTE 2 The creepage distance and clearance values shown are based on a maximum supply voltage tolerance of ±10 %.

NOTE 3 At 10 V and below, the value of CTI is not relevant and materials not meeting the requirement for material group IIIa may be acceptable.

NOTE These examples are identical with those given in IEC 60664-1

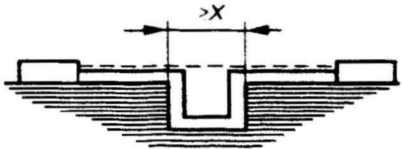
Example 1



Condition: Path under consideration includes a parallel- or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

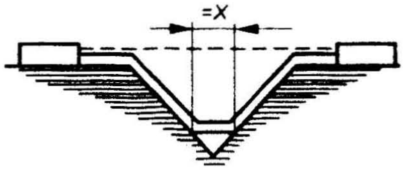
Example 2



Condition: Path under consideration includes a parallel-sided groove of any depth *d* equal to or more than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove.

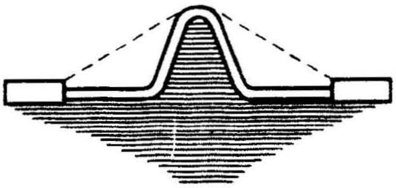
Example 3



Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the groove but "short circuits" the bottom of the groove by X mm link.

Example 4



Condition: Path under consideration includes a rib.

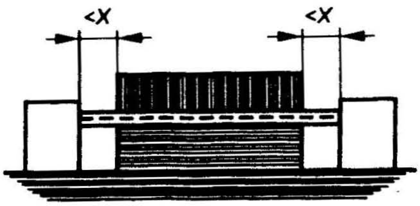
Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

- - - - - - 1 ▭ 2

1 clearance

2 creepage distance

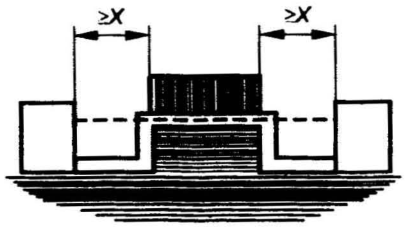
Example 5



Condition: Path under consideration includes an uncemented joint with groove less than *X* mm wide on each side.

Rule: Creepage and clearance path is the "line of sight" distance shown.

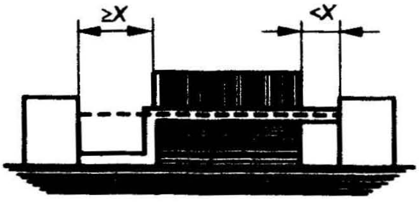
Example 6



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than *X* mm wide on each side.

Rule: Clearance is the "line of sight" distance. Creepage path follows the contour of the grooves.

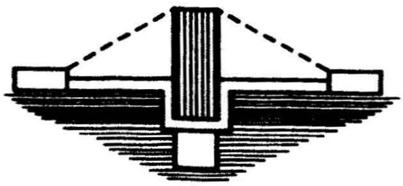
Example 7



Condition: Path under consideration includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than *X* mm wide.

Rule: Clearance and creepage paths are as shown.

Example 8



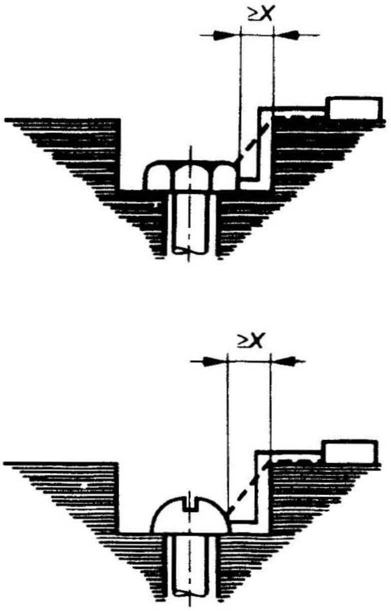
Condition: Creepage distance through uncemented joint is less than creepage distance over barrier.

Rule: Clearance is the shortest direct air path over the top of the barrier.

- - - - - 1 ▭ 2

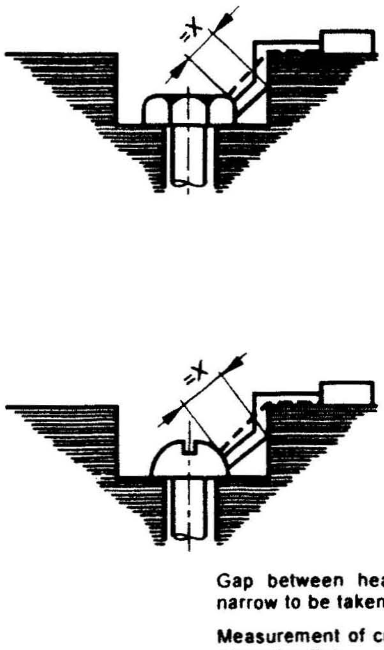
1 clearance 2 creepage distance

Example 9



Gap between head of screw and wall of recess wide enough to be taken into account.

Example 10



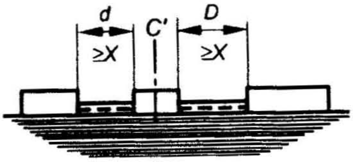
Gap between head of screw and wall of recess too narrow to be taken into account.

Measurement of creepage distance is from screw to wall when the distance is equal to X mm.

- - - - - 1 ▭ 2

1 clearance 2 creepage distance

Example 11



Clearance is the distance *d* + *D*

Creepage distance is also *d* + *D*

C' conductive part interposed in the insulating path between the conductors

- - - - - - 1　　▭ 2

1 clearance　　2 creepage distance

Figure 1 – Determination of creepage distances and clearances

4.4 Creepage distances

4.4.1 The required values of creepage distance are dependent on the working voltage, the resistance to tracking of the electrical insulating material and its surface profile.

Table 2 gives the grouping of electrical insulating materials according to the comparative tracking index (CTI) determined in accordance with IEC 60112. Inorganic insulating materials, for example glass and ceramics, do not track and need not therefore be subjected to the determination of the CTI. They are conventionally classified in material group I.

The grouping given in Table 2 is applied to insulating parts without ribs or grooves. If there are ribs or grooves in accordance with 4.4.3, the minimum permissible creepage distances for working voltages up to 1 100 V shall be based on the next highest material group, for example material group I instead of material group II.

NOTE 1 The material groups are identical with those given in IEC 60664-1.

NOTE 2 Transient overvoltages are ignored as they do not normally influence tracking phenomena. However, temporary and functional overvoltages may have to be considered, depending upon the duration and frequency of occurrence (see IEC 60664-1 for additional information).

Table 2 – Tracking resistance of insulating materials

Material group	Comparative tracking index (CTI)
I	600 ≤ CTI
II	400 ≤ CTI < 600
IIIa	175 ≤ CTI < 400

4.4.2 Creepage distances between bare conductive parts at different potentials shall be as given in Table 1, with a minimum value for external connections of 3 mm, and shall be determined as a function of the working voltage specified by the manufacturer of the apparatus.

NOTE For requirements for lamps with screw caps, see 5.3.3.1.

4.4.3 In determining the creepage distance, Figure 1 illustrates the features to be taken into account and the appropriate creepage distance. The value of dimension "X" is 2,5 mm.

The effects of ribs and grooves may be taken into account provided that

a) ribs on the surface are at least 2,5 mm high and of a thickness appropriate to the mechanical strength of the material with a minimum value of 1,0 mm;

b) grooves on the surface are at least 2,5 mm deep and at least 2,5 mm wide. If the associated clearance is less than 3 mm, the minimum groove width may be reduced to 1,5 mm.

NOTE 1 Projections above or depressions below the surface are considered as being either ribs or grooves, irrespective of their geometric form.

NOTE 2 Cemented constructions (see IEC 60079-0) are considered to be solid parts.

4.5 Solid electrical insulating materials

4.5.1 The term solid electrical insulating materials describes the final form and not necessarily the form in which they are initially applied; for example, insulating varnishes when cured are considered as being solid electrical insulating materials.

4.5.2 The mechanical characteristics of the materials that affect their functional behaviour, for example strength and rigidity, shall be satisfactory either

a) at a temperature up to at least 20 K above the maximum temperature attained in rated service, and at least 80 °C, or

b) for insulated windings (see 4.7.3 and Table 3), for internal wiring (see 4.8) and for cables permanently connected to electrical apparatus, up to the maximum temperature attained in rated service.

4.5.3 Insulating parts made of plastics or laminates, where the original surface is removed during manufacture, shall be coated with an insulating varnish having at least the same grading according to CTI as the original surface. This requirement does not apply to materials where these actions have not affected the grading according to CTI or where the specified creepage distance is provided by other parts not subjected to these actions.

4.6 Windings

4.6.1 Insulated conductors shall comply with the requirements of either 4.6.1.1 or 4.6.1.2.

4.6.1.1 The conductors shall be covered with at least two layers of insulation, only one layer of which may be enamel.

4.6.1.2 Enamelled round winding wires shall be in accordance with either:

a) grade 1 of IEC 60317-3, IEC 60317-7, IEC 60317-8, or IEC 60317-13 provided that:
   - when tested in accordance with Clause 13 of IEC 60317-3, IEC 60317-7, IEC 60317-8 or IEC 60317-13 there shall be no failure with the minimum values of breakdown voltage listed for grade 2; and that
   - when tested in accordance with Clause 14 of IEC 60317-3, IEC 60317-7, IEC 60317-8 or IEC 60317-13 there shall be not more than six faults per 30 m of wire irrespective of diameter; or

b) grade 2 of IEC 60317-3, IEC 60317-7, IEC 60317-8, or IEC 60317-13; or

c) grade 3 of IEC 60317-3, IEC 60317-7, IEC 60317-8, or IEC 60317-13.

4.6.2 Windings, after having been fastened or wrapped, shall be dried to remove moisture before impregnation with a suitable impregnating substance. Except as limited by 5.2.5, dipping, trickling or vacuum impregnation is acceptable. Coating by painting or spraying is not recognized as impregnation.

The impregnation shall be carried out according to the specific instructions of the manufacturer of the impregnating substance used and in such a way that the spaces between the conductors are filled as completely as possible and that good cohesion between the conductors is achieved.

This does not apply to fully insulated coils and conductors of windings if, prior to their fitting into the electrical apparatus, the slot portions and end windings of these coils and conductors have been impregnated, provided with filling material, or otherwise insulated in an equivalent manner, and if, after assembly, they are no longer accessible for the stated insulating procedures.

If impregnating substances containing solvents are used, the impregnation and drying processes shall be carried out at least twice.

4.6.3 The minimum nominal conductor dimension of wires used for windings shall be 0,25 mm.

NOTE 1 The minimum dimension is the diameter of a round conductor or the smallest dimension of a rectangular conductor.

NOTE 2 Windings made with wire having a minimum nominal conductor dimension less than 0,25 mm can be protected by another of the standard types of protection listed in IEC 60079-0.

4.6.4 Sensing elements of resistance temperature detectors (RTDs) are not considered to be windings, but when applied to the windings of rotating electrical machines, they shall be impregnated or sealed with the windings by the manufacturer.

NOTE When RTD's are applied outside of the slots of high-voltage machines, the RTD should be located in an earthed area.

4.7 Temperature limitations

4.7.1 General

No part of an electrical apparatus shall attain a temperature in excess of that determined by the thermal stability of the materials used. Furthermore, no surface of any part of an electrical apparatus including the surface of internal parts to which the potentially explosive atmosphere might have access shall attain a temperature in excess of the maximum surface temperature prescribed in IEC 60079-0 except for lamps in luminaires for which the requirement is given in 5.3.4.

For electrical machines, determination of the maximum surface temperature may alternatively be conducted at the worst case test voltage within "zone A" per IEC 60034-1. In this case, the equipment shall be marked with the symbol "X" in accordance with item i) of 29.2 of IEC 60079-0 and the specific condition of use shall include the information that the surface temperature determination was based on operation within Zone A (IEC 60034-1), typically ±5 % of rated voltage.

NOTE There are two conditions to be satisfied, either of which may prove to be the limiting feature for a particular apparatus or part of an apparatus.

4.7.2 Conductors

The permissible temperature of conductors and other metal parts is further limited by

a) reduction of mechanical strength,

b) unacceptable mechanical stress due to thermal expansion,

c) damage to neighbouring electrical insulating parts.

In determining the temperature of the conductors, both the self-heating of the conductors and the effect of heating by neighbouring parts shall be taken into account.

4.7.3 Insulated windings

The limiting temperature of insulated windings shall not exceed the values given in Table 3 which take account of the thermal endurance of electrical insulating materials, provided that the electrical apparatus still complies with the requirements of 4.7.1.

Table 3 – Limiting temperatures for insulated windings

	Method of temperature measurement (see Note 1)	**Thermal class according to IEC 60085 (see Note 2)**				
		105 (A)	120 (E)	130 (B)	155 (F)	180 (H)
1 Limiting temperature in rated service:		°C	°C	°C	°C	°C
a) insulated single layer winding	Resistance or thermometer	95	110	120	130	155
b) other insulated windings	Resistance	90	105	110	130	155
	Thermometer	80	95	100	115	135
2 Limiting temperature at end of time t_E (see Note 3)	Resistance	160	175	185	210	235

NOTE 1 Measurement by thermometer is permissible only when measurement by change of resistance is not possible. In this context, "thermometer" has the same meaning as in IEC 60034-1 (for example a bulb thermometer, or a non-imbedded thermocouple or resistance temperature detector (RTD) applied to the points accessible to the usual bulb thermometer).

NOTE 2 As an interim measure until values have been prescribed, the higher thermal classes of insulating material denoted by figures in IEC 60085 are considered as subject to the limiting temperatures given for class 180 (H).

NOTE 3 These values result from the ambient temperature, the temperature rise of the winding in rated service and the increase of temperature during time t_E.

4.7.4 Winding protection

Windings shall be protected by suitable devices to ensure that the limiting temperature (see 4.7.1, 4.7.2, and 4.7.3) cannot be exceeded in service. Such devices are not required if the temperature of the windings does not exceed the limiting temperature given for rated service in 4.7.3 even when the windings are subjected to continuous overload or if the windings cannot be subjected to overload.

NOTE 1 The protective device (sensor) may be inside and/or outside the electrical apparatus.

NOTE 2 Electrical faults in insulated windings are excluded as a service condition. The requirements of 4.6 and 4.7 are intended to reduce the likelihood of such faults.

4.8 Wiring internal to apparatus

Wiring which might come into contact with a conductive part shall be either mechanically protected, secured, or routed to avoid insulation damage.

4.9 Degrees of protection provided by enclosures

4.9.1 The degrees of protection as defined in IEC 60034-5 and IEC 60529 shall be as prescribed in a) or b), unless otherwise specified in 4.9.2, 4.9.3, or Clause 5.

a) Enclosures containing bare conductive live parts shall provide at least the degree of protection IP54.

b) Enclosures containing only insulated conductive live parts as in 4.5 shall provide at least the degree of protection IP44.

4.9.2 The enclosure of an electrical apparatus may be provided with drain holes or ventilation openings to prevent the accumulation of condensation. The requirements are dependent upon the apparatus grouping as follows.

a) Apparatus group I – compliance with 4.9.1 is required.

b) Apparatus group II – the inclusion of the drain holes or ventilation openings may reduce the degree of protection provided by the enclosure according to 4.9.1 , but shall not be below IP44 in item a) of 4.9.1 or IP44 in item b) of 4.9.1.

When the presence of drain holes or ventilation openings reduces the degree of protection below the requirements of 4.9.1, the details of the drain holes or ventilation openings, including position and dimensions, shall be stated by the manufacturer and included in the descriptive documents according to IEC 60079-0. The marking of apparatus with drain holes and ventilation openings that reduce the degree of protection shall include the symbol "X" in accordance with item i) of 29.2 of IEC 60079-0 and the reduced degree(s) of protection provided by enclosure shall be shown on the certificate.

4.9.3 When there are circuits or systems with type of protection "i" according to IEC 60079-11, or parts of these, within the enclosure, either:

a) the covers of the enclosure permitting access to energized non-intrinsically-safe circuits shall have a label per item a) of Table 12; or

b) all bare live parts not protected by the type of protection "i" shall have a separate internal cover providing at least the degree of protection IP30 when the enclosure of the apparatus is open.

   In addition, the internal cover shall have a label per item b) of Table 12 or other wording that would otherwise be required by IEC 60079-0 to be on the cover of the enclosure of the apparatus.

   The cover of the enclosure of the apparatus shall have a label per item c) of Table 12.

NOTE The purpose of the internal cover, when fitted, is to provide a minimum acceptable degree of protection against the access to energized non-intrinsically-safe circuits when the enclosure is opened for short periods to permit live maintenance of intrinsically-safe circuits. The cover is not intended to provide protection from electrical shock.

4.10 Fasteners

For group I electrical apparatus containing bare live parts, special fasteners according to IEC 60079-0 shall be used.

5 Supplementary requirements for specific electrical apparatus

5.1 General

These requirements supplement those of Clause 4 of this standard which are applicable also, unless otherwise stated, to the specific electrical apparatus considered in 5.2 to 5.9 and also to the other electrical apparatus considered in 5.10.

5.2 Rotating electrical machines

5.2.1 Degrees of protection provided by machine enclosures

As an exception to the requirements given in 4.9 for protection against the ingress of solid foreign bodies and water, the following degrees of protection suffice in the cases stated for the enclosures of rotating machines (except for terminal boxes and bare conductive parts) installed in clean environments and regularly supervised by trained personnel

- IP23 for apparatus group I;
- IP20 for apparatus group II.

Solid foreign bodies shall be prevented from falling vertically through the ventilating openings into the enclosures of rotating machines.

The marking of rotating machines designed for use only in clean environments shall include the symbol "X", in accordance with i) of 29.2 of IEC 60079-0 and the degree of protection provided by enclosure shall be shown on the certificate.

5.2.2 Internal fans

Internal fans shall comply with the requirements for clearances and materials specified for external fans in IEC 60079-0.

5.2.3 Minimum radial air gap

The minimum radial air gap between the stator and the rotor (in the active core area) when the rotating machine is at rest, shall be not less than the value given by the following formula

Minimum radial air gap, in mm:

$$\left[0{,}15 + \frac{D-50}{780}\left(0{,}25 + \frac{0{,}75\,n}{1\,000}\right)\right] r\,b$$

where

D is the rotor diameter, in mm, which in the formula for the minimum radial air gap is subject to a minimum value of 75 mm and a maximum value of 750 mm,

n is the maximum rated speed in r/min and is subject to a minimum value of 1 000,

r has the value given by the following formula and is subject to a minimum value of 1,0

$$r = \frac{\text{core length}}{1{,}75 \times \text{rotor diameter, } D} \text{ in mm}$$

b has the value of 1,0 for machines with rolling bearings or 1,5 for machines with plain bearings.

NOTE The minimum radial air gap is not directly proportional to the supply frequency or number of poles as can be seen from the example of a 2-pole or 4-pole motor with rolling bearings designed for a 50 Hz/60 Hz supply and having a rotor with a diameter of 60 mm and a core length of 80 mm.

D is then taken as 75, the minimum value;

n as 3 600, the maximum value,

b as 1.0,

r = 80/(1.75 × 60), i.e. approximately 0.76 and therefore taken as 1.0

when the minimum radial air gap becomes

$$\left[0{,}15 + \frac{75 - 50}{780}\left(0{,}25 + \frac{0{,}75 \times 3\,600}{1\,000}\right)\right]1{,}0 \times 1{,}0$$

or approximately 0.25 mm.

5.2.4 Machines with cage rotors

5.2.4.1 In addition to the requirements of 5.2.1, 5.2.2 and 5.2.3, the requirements of this subclause apply to rotating machines with cage rotors, including synchronous machines with "cage rotor" starting or damping windings.

5.2.4.2 The bars of cage rotors shall fit tightly in the slots and shall be brazed or welded to the short-circuiting rings unless the bars and rings of the cages are manufactured as a single unit.

NOTE The bars and rings of cage rotors are not considered to be bare conductive parts in applying 4.3, 4.4, 4.9 and 5.2.1.

5.2.4.3 The rotor construction shall be assessed for possible air gap sparking.

If the total sum of the factors determined by Table 4 is greater than 6, the machine or a representative sample shall be tested in accordance with 6.2.3.2, or the machine shall be constructed to allow special measures to be employed to ensure that its enclosure does not contain an explosive gas atmosphere at the time of starting. The machine marking shall include the symbol "X", in accordance with item i) of 29.2 of IEC 60079-0, and the specific conditions of use outlined in the certificate shall include details to allow appropriate measures to be selected.

NOTE 1 Special measures that can be applied include pre-start ventilation or the application of fixed gas detection inside the machine enclosure.

NOTE 2 For motors driving high inertia loads or intended to be auto re-started, these tests are only representative of operating conditions away from torsional resonance of the complete drive train and where out-of-phase re-starting can be excluded. These special applications need to be carefully coordinated between the manufacturer and the user.

Alternatively, where the starting current of the machine is limited to 300 % of rated current, I_N, the assessment of possible air gap sparking is not required. Where the use of reduced voltage starting is required to reduce the maximum starting current to 300 % of the rated current, I_N, the machine marking shall include the symbol "X", in accordance with item i) of 29.2 of IEC 60079-0, and the specific conditions of use shall include that the motor is suitable only for reduced voltage starting which limits the starting current to 300 % of the rated current.

NOTE 3 The use of a converter to provide the current limitation is generally an acceptable solution. For other reduced voltage starting methods, the motor and the reduced-voltage starter need to be carefully coordinated.

Table 4 – Potential air gap sparking risk assessment for cage rotor ignition risk factors

Characteristic	Value	Factor
Rotor cage construction	Uninsulated bar fabricated rotor cage	3
	Open slot cast rotor cage ≥ 200 kW per pole	2
	Open slot cast rotor cage < 200 kW per pole	1
	Closed slot cast rotor cage	0
	Insulated bar rotor cage	0
Number of poles	2-pole	2
	4- to 8-pole	1
	> 8-pole	0
Rated output	> 500 kW per pole	2
	> 200 kW to 500 kW per pole	1
	≤ 200 kW per pole	0
Radial cooling ducts in rotor	Yes: L <200 mm (see Note 1)	2
	Yes: L >200 mm (see Note 1)	1
	No	0
Rotor or stator skew	Yes: > 200 kW per pole	2
	Yes: ≤ 200 kW per pole	0
	No	0
Rotor overhang parts	Non-compliant (see Note 2)	2
	Compliant (see Note 2)	0
Limiting temperature	>200 °C	2
	135 °C < T ≤ 200 °C	1
	≤ 135 °C	0

NOTE 1 L is the length of end packet of core. Experimental tests have shown that sparking occurs predominantly in ducts near the ends of the core.

NOTE 2 Rotor overhang parts should be designed to eliminate intermittent contact and to operate within the temperature classification. Compliance with this ruling gives a factor of 0, otherwise it is 2.

5.2.4.4 The limiting temperature of the rotor shall not be exceeded, even during starting. The limiting temperature is the lesser of 300 °C or the value specified in 4.7.

NOTE Parts in the leakage flux path may need to be non-magnetic or insulated, otherwise their temperatures may exceed those of the rotor bars under stall conditions. Examples of such parts may include retaining rings, balance disks, centring rings, fans or air shrouds.

5.2.4.4.1 When intended for use with a current-dependent device to protect against exceeding the limiting temperature, the starting current ratio I_A/I_N and the time t_E shall be determined and marked in accordance with 9.1.

The length of time t_E shall be such that, when the machine is stalled, it can be disconnected by the current-dependent protective device before time t_E has elapsed. In general, this is possible if the minimum values for t_E given in Figure 2 as a function of the starting current ratio I_A/I_N are exceeded. Values of time t_E below the values in Figure 2 are permissible only if a suitable overload protective device is used for the machine and it is shown to be effective by test. The devices shall be specified by marking on the machine in accordance with item g) of 9.1.

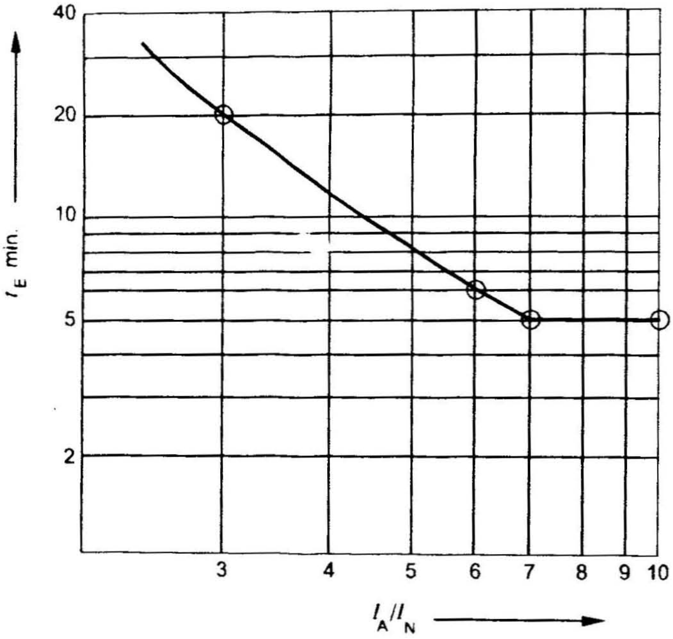


Figure 2 – Minimum values of the time t_E of motors in relation to the starting current ratio I_A/I_N

In no case

- shall the value of time t_E be less than 5 s when using a current-dependent protective device,
- shall the value of the starting current ratio I_A/I_N exceed 10.

5.2.4.4.2 When intended for use with winding temperature sensors associated with protective devices to protect against the occurrence of non-permissible temperatures, the starting current ratio I_A/I_N shall be determined and marked in accordance with 9.1. Time t_E is not required to be determined and marked. Winding temperature sensors associated with protective devices shall be considered adequate for the thermal protection of the machine if the requirements of 4.7.4 are satisfied even when it is stalled. The requirements for associated protective devices shall be specified by marking on the machine in accordance with item g) of 9.1.

In no case shall the value of the starting current ratio I_A/I_N be more than 10.

NOTE Larger machines are frequently rotor limited and it is not generally practical to limit the rotor temperature by the use of stator winding temperature sensors.

5.2.4.5 Converter-fed motors shall be tested and certified for this duty as a unit in association with converter specifications as detailed in the descriptive documents according to IEC 60079-0. The test shall be performed with the protective device provided or shall be evaluated in accordance with 5.2.4.7.

NOTE Additional information on the application of converter-fed motors can be found in IEC 60034-17. Major concerns include over-temperature, high frequency and overvoltage effects as well as bearing currents. These effects can be reduced by using low-pass filters to lower the total harmonic distortion of the converter output waveform

5.2.4.6 Information on the thermal protection of cage motors by overload protective devices is given in Annex C.

5.2.5 Winding requirements

For polyphase windings rated 200 V or higher, supplemental phase insulation (in addition to varnish) shall be provided between the phases of random windings

The minimum clearance between a stator winding overhang and the enclosure shall not be less than 3 mm.

For windings rated <1 000 V, the requirements for coil impregnation shall be either those of 4.7.2 or those applying for windings rated >1 000 V.

For windings rated >1 000 V, coils shall be from a form-wound and vacuum pressure impregnated (VPI) insulation system or a resin-rich insulation system.

5.2.6 Stator winding terminals

Stator winding terminals shall not exceed the limiting temperature (see 4 7) with starting current I_A applied for a time period of t_E.

5.2.7 Stator winding insulation system

If the rated voltage exceeds 1 kV,

type tests in accordance with 6.2.3.1 shall be conducted, and

- the machine shall be fitted with anti-condensation heaters, and
- the machine shall be constructed to allow additional measures to be employed to ensure that its enclosure does not contain an explosive gas atmosphere at the time of starting The machine instructions provided, in accordance with IEC 60079-0, shall include information on the implementation, where required, of the additional measures

NOTE 1 Measures that can be applied include pre-start ventilation or the application of fixed gas detection inside the machine enclosure. Other methods may be applied with the agreement of the manufacturer, testing laboratory, and the user, as appropriate.

NOTE 2 The application of pre-start ventilation and the maintenance of the machine are the responsibility of the user who shall refer to IEC 60079-14 and IEC 60079-17 for guidance Until these standards contain sufficient information, Annex G provides guidance.

5.2.8 Bearing seals and shaft seals

5.2.8.1 Non-rubbing seals and labyrinths

For rolling element bearings the minimum radial or axial clearance between the stationary and rotating parts of any non-rubbing seal or labyrinth seal shall be not less than 0,05 mm For sliding element (sleeve) bearings, this clearance shall be 0.1 mm The minimum clearance shall apply for all possible positions of the shaft within the bearings

NOTE The axial movement in a typical ball bearing is likely to be up to 10 times the radial movement

5.2.8.2 Rubbing seals

Rubbing seals shall be either lubricated or made of material having a low coefficient of friction, for example polytetrafluoroethylene (PTFE). In the former case, the design of the bearing shall be such that a supply of lubricant to the seal is maintained.

Bearings with covers supplied as an integral part of the bearing by the bearing manufacturer (that is to say, "sealed for life" bearings) are exempted from this requirement.

Rubbing seals shall be assessed in accordance with 4.7.

NOTE 1 In order that excess temperatures are not generated in service, information on any maintenance required to ensure continued compliance with the requirements of 5.2.8 should be provided by the manufacturer.

NOTE 2 Rubbing seals which reduce their cross-section when ageing (for example felt sealing rings) are considered to meet the requirements when the temperature is assessed to be within the limits during new condition. Elastic seals which lift off during rotation (for example V rings) are also considered to meet the requirements.

NOTE 3 At the present time, no suitable experimental test exists to demonstrate that a given type of bearing has a very low risk of failing in service. It is therefore paramount that the manufacturer pays attention to good design, construction, lubrication, cooling, monitoring and/or maintenance procedures, in an attempt to minimize the risk of a potential ignition source arising from a rolling bearing failure.

5.3 Luminaires

NOTE 1 This subclause does not give requirements for signal and similar small lamps (see 5.10).

NOTE 2 To limit heating of a neutral conductor, third order harmonic currents drawn by the luminaire should be limited to 30 % of the fundamental frequency current.

5.3.1 Light source

The light source shall be one of the following:

a) fluorescent lamps of the cold starting type with single-pin caps (Fa6) in accordance with IEC 60061-1;

b) tubular fluorescent bi-pin lamps with G5 or G13 lamp caps according to IEC 61195. Pins shall be made of brass. Lampholders and sockets shall comply with 5.3.3. Such lamps shall be connected in a circuit in which they start and run without preheating of the cathodes;

c) tungsten filament lamps for general lighting service in accordance with IEC 60064 and IEC 60432-1.

NOTE Other light sources can be considered using 5.10.

5.3.2 Minimum distance between lamp and protective cover

For fluorescent tubes, the distance between the lamp and a protective cover shall be not less than 5 mm unless the protective cover is an outer tube, in which case the minimum distance is 2 mm.

For other lamps, the distance between the lamp and the protective cover shall be not less than the value given in Table 5, according to the lamp wattage.

Table 5 – Minimum distance between lamp and protective cover

Lamp wattage, P W	Minimum distance mm
$P \le 60$	3
$60 < P \le 100$	5
$100 < P \le 200$	10
$200 < P \le 500$	20
$500 < P$	30

5.3.3 Lampholders and lamp caps

5.3.3.1 Screw lampholders and lamp caps

Screw lampholders together with the appropriate lamp caps shall comply with

- the test requirements for non-transmission of an internal ignition of IEC 60079-1 for apparatus group I or apparatus group IIC, as appropriate, both when inserted and at the moment of making or breaking of the electrical contact, or
- the electrical contact between the lampholder and the lamp cap shall be such that on insertion or removal of the lamp cap, the making or breaking of the current occurs only in a separate enclosure complying with the constructional and test requirements of apparatus group I or apparatus group IIC of IEC 60079-1, as appropriate.

Screw lampholders shall prevent self-loosening of the lamp after insertion. For lamp caps other than E10, this shall be shown by meeting the mechanical test of 6.3.1.

NOTE The threaded part of the lampholder should be of material which is resistant to corrosion under the likely conditions of service.

At the moment of contact separation during unscrewing of the lamp, at least two complete threads shall be engaged.

Lamps with screw caps provided as part of a luminaire need not comply with the requirements of 4.3 and 4.4.2 if they comply with the minimum requirements for creepage distances and clearances in Table 6. The insulating material of the lamp cap shall comply with material group I in Table 2.

Table 6 – Creepage distances and clearances for screw lamp caps

Voltage, U V	Creepage distance and clearance mm
$U \le 63$	2
$63 < U \le 250$	3

NOTE 1 Voltages shown are derived from IEC 60664-1 and are based on the rationalization of supply voltages given in Table 3b IEC 60664-1. When determining the required values for creepage and clearance, the voltage value in the table may be increased by a factor of 1.1 in order to recognize the range of rated voltages in common use.

NOTE 2 The creepage distance and clearance values shown are based on a maximum supply voltage tolerance of ±10 %.

NOTE 3 At 10 V and below, the value of CTI is not relevant and materials not meeting the requirement for material group I may be acceptable.

5.3.3.2 Other lampholders and lamp caps

The enclosure formed by the lampholder and the lamp cap, both when inserted and at the moment of making or breaking of the electrical contact, shall comply with the test requirements for non-transmission of an internal ignition of IEC 60079-1 for apparatus group I or apparatus group IIC, as appropriate.

NOTE Lampholders and lamp caps, which together after mounting comply with one of the standard types of protection in Clause 1 of IEC 60079-0 are also permitted.

Lampholders for tubular fluorescent lamps shall comply with the dimensional requirements of data sheet Fa6 of IEC 60061-2 or with G5 or G13 of IEC 60400.

For other lampholders used with lamps having cylindrical caps, the width of the joint between the lampholder and the cap shall, at the moment of making or breaking of contact, be at least 10 mm.

5.3.3.3 Requirements for electrical contact between the lampholder and lamp cap

The electrical contact to the lamp cap shall be effected:

a) in the case of screw caps
   - to the bottom contact of the lamp cap through resilient or spring contact elements with a force of at least 15 N, and
   - to the lamp cap through at least two threads or through one or more spring elements with a total contact force of at least 30 N;

b) in the case of cylindrical pin caps through spring elements having a contact force of at least 10 N;

c) in the case of cylindrical plug-in caps, where the design shall not allow electrical sparking in or external to the joint between the cap and holder, through spring elements having a contact force of at least 10 N;

d) in the case of caps where, on removal from the respective lampholder, the circuit is interrupted in a separate flameproof enclosure (complying with IEC 60079-1) in such a way that the contact force exerted by the spring elements on the caps is not less than 7,5 N at the moment of circuit interruption.

The above minimum values prescribed for the contact force apply with the lamp fitted to the holder and ready for use.

NOTE The force of the contact elements should not be affected significantly by heating and other effects to be expected during operation.

5.3.4 Surface temperature of lamps

The maximum surface temperature prescribed by IEC 60079-0 may be exceeded when the highest surface temperature of the lamp inside the luminaire is at least 50 K below the lowest temperature of ignition inside the luminaire of the potentially explosive atmosphere for which the luminaire is intended, as determined by tests made under the most unfavourable conditions of use. This dispensation is only valid for the gas atmospheres indicated on the certificate, these being those for which the tests have given satisfactory results.

NOTE Measurements on existing luminaires have established that the temperatures at which ignition will occur inside the luminaires are considerably higher than the ignition temperatures measured in accordance with IEC 60079-4.

5.3.5 Temperature of lamp caps

The temperature at the rim of the lamp cap and at the soldering point of the lamp cap shall not exceed the limiting temperature. The limiting temperature is the lesser of 195 °C or the value specified in 4.7.

5.3.6 Limiting temperatures

The limiting temperature of ballasts, lampholders and lamps shall not be exceeded even in the case of ageing lamps. The luminaire shall be subjected to the type test of 6.3.2 The stabilized temperature of the ballast, lampholder, and the lamp itself shall be less than the limiting temperature, or a cut-off device shall be used to switch off the power before the limiting temperature is exceeded.

5.3.7 Luminaires for tubular fluorescent bi-pin lamps

5.3.7.1 General

Luminaires for tubular fluorescent bi-pin lamps shall additionally comply with the following requirements.

5.3.7.2 Maximum ambient temperature

The maximum ambient temperature for a luminaire with tubular fluorescent bi-pin lamps employing an electronic ballast shall not exceed 60 °C.

5.3.7.3 Temperature class

As the limiting temperature of a luminaire with tubular fluorescent bi-pin lamps employing an electronic ballast will exceed the temperatures appropriate for temperature classes T5 and T6, those temperature classes shall not be permitted. See 6.3.2.3.

5.3.7.4 Lampholders for bi-pin lamps shall comply with the following requirements when mounted in the luminaire.

- The mechanical dimensions and the mounting conditions in the luminaire shall take into account the mechanical values and the tolerances specified for the lamp in IEC 60061-1, IEC 61195 and IEC 60400.
- The lampholder shall comply with the requirements for G5 or G13 in IEC 60400.
- The two pins on each lamp cap shall be connected in parallel, either within the lampholder, or directly adjacent within the luminaire wiring. The current-carrying capacity of each single pin connection shall be rated for the whole current of the lamp, to achieve redundancy.
- The insulating material of the lampholder shall comply with the requirements for non-metallic materials in IEC 60079-0.
- The electrical contact system for each lamp pin shall be independent of the presence of the other pin.
- The pins of the lamp shall be supported in a manner that minimizes distortion when they are subject to contact side pressure.

5.3.7.5 If an enhanced voltage is used to initiate discharge within the lamp (for example from an electronic starter/ignitor), the peak value of that voltage divided by $\sqrt{2}$ shall be used to determine the r.m.s. value used in Table 1. The metal ring of the lamp tube shall be assumed to be at the electrical potential of pins.

If a device within the electronic ballast ensures that starting impulses will be stopped after a maximum time period of 5 s and that a reset is only possible after switching off the supply of the luminaire, then the factor $\sqrt{2}$ may be increased to 2,3.

5.3.7.6 The maximum values for torque and/or force at each end of the lamp occurring when fitting or removing the lamp in the luminaire shall be not more than 50 % of the limit values for unused lamps that may be applied to the pins of the lamp specified in Table 1 of IEC 61195.

5.3.7.7 The electrical contact between each pin of the lamp and the lampholder shall be reliable even under corrosion and vibration conditions. The type tests are given in 6.3.3 and 6.3.4.

5.3.7.8 If an isolation switch is provided in accordance with IEC 60079-0, it shall de-energize each lampholder when the protective cover is removed. When such an isolation switch is provided:

a) the switch shall be an isolator in accordance with IEC 60947-1 and IEC 60664-1, overvoltage category III, or the contact clearance in the neutral and/or the supply lines shall be at least 2,5 mm each for a maximum supply voltage of 300 V (d.c. or r.m.s.) to achieve the clearance of 2,5 mm, two separate clearances of at least 1,25 mm each may be added together;

b) the contacts shall open upon removal of the protective cover of the luminaire;

c) the switch and its operation shall not be capable of being readily defeated without the use of a tool;

NOTE One solution may be IP2X protection according to IEC 60529 of the operating part of the switch. Another solution may be that the switch can only be closed (after operating) by means of a tool.

d) the switch shall be protected using a suitable type of protection.

If an isolating switch is not provided, the luminaire shall be marked per item b) of Table 12 to indicate that the luminaire is not to be opened when energized.

5.4 Caplights and handlights

NOTE The requirements for caplights for group I are in IEC 62013-1.

The lamp shall be protected against mechanical damage by a protective cover. The distance between the protective cover and the lamp when the latter is securely inserted shall be at least 1 mm. Alternatively, the lamp may be held in contact with a spring-loaded lampholder by being in contact with the protective cover, in which case the spring travel shall be at least 3 mm. The protective cover shall be

a) protected by a guard, or

b) if not exceeding 5 000 mm^2 in area, protected by a protruding rim with a minimum height of 2 mm, or

c) if exceeding 5 000 mm^2 in area, able to withstand the mechanical test requirements specified for guards and fan hoods in IEC 60079-0.

Switching devices in the lamp circuit which produce sparks or arcs in normal service, including devices such as reed switches where the sparks or arcs are produced in hermetically sealed enclosures, shall either be mechanically or electrically interlocked to prevent contact separation within the hazardous area or they shall be protected by one of the standard types of protection listed in IEC 60079-0.

5.5 Measuring instruments and instrument transformers

5.5.1 Measuring instruments and instrument transformers shall be able to withstand continuously 1,2 times their rated current and/or their rated voltage, as appropriate, without exceeding the limiting temperatures according to 4.7.

5.5.2 Current transformers and the current-carrying parts of measuring instruments (excluding voltage circuits) shall be able to withstand thermal and dynamic stresses resulting from currents equal to at least the values stated in Table 7 for the periods as indicated in 6.4 with no reduction in their level of security against explosions.

Table 7 – Resistance to the effect of short-circuit currents

Current	Current transformer and current-carrying parts of measuring instruments
I_{th}	≥ 1,1 × I_{sc} (see 3.10 and Note 2)
I_{dyn}	≥ 1,25 × 2,5 I_{sc} (see Notes 1 and 2)

NOTE 1 2,5 I_{sc} is the maximum peak value of the short-circuit current

NOTE 2 Factors 1,1 and 1,25 are safety factors. It follows that the r.m.s. value of the permissible short-circuit current in service may not exceed $I_{th}/1,1$ and its peak value may not exceed $I_{dyn}/1,25$.

5.5.3 The temperature attained during the passage of a current equal to the rated short-time thermal current I_{th} shall not exceed the limiting temperature specified in 4.7 and in no case shall it exceed 200 °C.

5.5.4 Where the current-carrying parts of measuring instruments are supplied by current transformers, the values of I_{th} and I_{dyn} need only equal the current flowing in the short-circuited secondary windings of the current transformer with its primary windings carrying the currents I_{th} and I_{dyn} applicable to them.

5.5.5 Measuring instruments with moving coils are not permitted.

5.5.6 If the secondary circuit of the current transformer extends outside the apparatus, the apparatus shall be marked with the symbol "X" according to 29.2 i) of IEC 60079-0 and the certificate shall advise of the need to guard against the secondary circuit becoming open-circuited in service.

NOTE If current transformers are fitted under open-circuit secondary conditions, they may be capable of producing voltages which are significantly in excess of the voltage rating of the terminals employed in the current transformer circuit. Dependent upon the circumstances of a particular installation, it may be appropriate to take precautions to ensure that dangerous open-circuit voltages cannot occur. For apparatus having current transformers connected to matching transformers in the switchgear (for example a differential protection system), consideration should be given to the effect at the apparatus of any possible disconnection of either set of transformers.

5.6 Transformers other than instrument transformers

Transformers other than instrument transformers for which the requirements are given in 5.5 shall be tested in accordance with 6.5.

5.7 Batteries

5.7.1 Secondary batteries with capacity greater than 25 Ah

5.7.1.1 General

Secondary batteries shall be of the lead-acid, nickel-iron or nickel-cadmium type and shall comply with the requirements of this standard. The test methods are given in 6.6.

NOTE Compliance with these requirements does not ensure safety during charging. The latter should therefore take place outside the hazardous area, unless other safety measures are applied.

5.7.1.2 Battery containers

All internal surfaces of the battery containers and of the covers, when of metallic material, shall be completely lined with an insulating layer; for covers, a suitable insulating paint can be sufficient. Internal surfaces shall not be adversely affected by the action of the electrolyte.

Battery containers including covers shall be designed so as to withstand mechanical stress when in use, including that due to transportation and handling. In order to achieve this, it may be necessary to incorporate partition walls in the containers.

If necessary, battery containers shall be provided with insulating barriers. Partition walls can be accepted as insulating barriers, if suitably constructed. Insulating barriers shall be positioned so as to prevent the development of a nominal voltage exceeding 40 V in any section. The insulating barriers shall be constructed in such a manner that the required creepage distance in service will not be reduced in an inadmissible way. The height of the insulating barriers shall be at least two-thirds the height of the cells. The method indicated in Figure 1, examples 2 and 3, shall not be used in the calculations of these creepage distances.

The creepage distance between the poles of adjacent cells and between these poles and the battery container shall be at least 35 mm. Where nominal voltages between adjacent cells of the battery exceed 24 V, these creepage distances shall be increased by at least 1 mm for each 2 V in excess of 24 V

The covers of battery containers shall be fixed in such a way that any inadvertent opening or displacement whilst in service is avoided.

Each cover shall be provided with a fastener complying with 9.1 of IEC 60079-0.

The cells shall be built into the battery containers in such a way that there is no significant displacement in service. The materials of terminal mountings and other built-in items (for example, packing and insulating barriers) shall be insulating, non-porous, resistant to the action of the electrolyte and not easily ignitable.

The extraction of liquid which may have entered battery containers without drain holes shall be possible without the removal of the cells.

Battery containers shall be provided with sufficient ventilation openings. Contrary to 4.9, degree of protection IP23 according to IEC 60529 is sufficient for battery containers.

NOTE The protection against access to hazardous parts and against solid foreign objects and the protection against ingress of water, contrary to IEC 60529, may be assessed on the basis of the technical documentation. If a practical test on IPX3 according to IEC 60529 is carried out and if water enters the battery container, then the insulation resistance test as described in 6.6.2 may be used to judge a harmful amount

The ventilation openings shall provide sufficient ventilation such that the hydrogen concentration in the battery container during the type test of 6.6.4 does not exceed 2 % by volume.

Plugs and sockets shall comply with the requirements of IEC 60079-0. This does not apply to plugs and sockets which can only be separated with the use of a tool and which bear a warning label per item d) of Table 12:

Positive and negative plugs of single-pole plugs and sockets shall be non-interchangeable.

The polarity of the battery and of plugs and sockets shall be marked in a durable and unambiguous manner.

Any other electrical apparatus affixed to or incorporated in the battery container shall comply with the requirements for the appropriate type of protection.

5.7.1.3 Cells

The cell lids shall be sealed to the cell containers so as to prevent detachment of the cell lid and leakage of the electrolyte. Readily ignitable materials shall not be used.

The positive and negative plates shall be supported effectively.

Each cell requiring maintenance of the electrolyte level shall be provided with a means of indicating that the electrolyte level lies between the minimum and maximum permissible levels. Precautions shall be taken to avoid excessive corrosion of the plate lugs and the busbars when the electrolyte is at the minimum level.

In each cell sufficient space shall be provided to prevent the cell overflowing due to expansion of the electrolyte and also for deposition of slurry. These spaces shall be related in volume to the anticipated life of the battery.

Filling and vent plugs shall be designed to prevent any ejection of the electrolyte under normal conditions of use. They shall be located in such a manner that they are easily accessible for maintenance.

A seal shall be provided between each terminal pole and the lid of the cell to prevent leakage of the electrolyte.

New batteries, fully charged and ready for service, shall have an insulation resistance of at least 1 MΩ between the live parts and the battery container.

NOTE Batteries in service should have an insulation resistance of at least 50 Ω per volt of nominal voltage with a minimum value of 1 000 Ω.

5.7.1.4 Connections

The intercell connectors between adjacent cells which can move relative to one another shall be non-rigid. When non-rigid intercell connections are used, each end of the connection shall be

a) welded or soldered into the terminal post, or

b) crimped into a copper sleeve cast into the terminal post, or

c) crimped into a copper termination screwed by a threaded fastening to an insert cast into the cell terminal post. The insert may be copper or other materials if the mechanical and thermal/electrical properties of the connection are found acceptable by the torque test of IEC 60079-0, and by satisfying the requirements of this subclause. The threaded joints shall be prevented from loosening.

In cases b) and c) the intercell connector shall be copper.

NOTE Although the word '"copper" is used in c) above, copper alloyed with a small amount of another metal (for example chromium or beryllium) is acceptable where it is necessary to improve the mechanical properties of the connection (for example to prevent stripping of screw threads in the copper insert). Where such alloys are used, it may be necessary to increase the contact area of the intercell connection to counteract any decrease in electrical conductivity caused by the other metal.

The connectors shall be able to carry the current required for the duty without exceeding the limiting temperature (see 4.5.2, 4.7.1, and 4.7.2). Where the duty cannot be defined, the battery shall be assessed at the discharge rate used by the battery manufacturer to determine the battery capacity. Where double connectors are used, each single connector shall be capable of carrying the total current without exceeding the limiting temperature.

All connectors exposed to attack by the electrolyte shall be suitably protected; for example, for lead-acid batteries, non-insulated connectors of metals other than lead shall be lead-coated. This does not apply to screw threads.

Live parts shall have insulating protection to avoid accidental contact when the battery cover is open.

5.7.2 Primary and secondary batteries with capacity up to 25 Ah

NOTE These requirements do not apply to batteries used as part of miner's caplights, which are dealt with in IEC 62013-1

Where cells are subject to encapsulation, care shall be taken to ensure that any pressure relief facilities are not obstructed. The vent size shall be sufficiently large to prevent dangerous pressurization of the encapsulated assembly at the most onerous predictable release rate from the battery. A minimum of one vent for each cell is required.

The encapsulation of cells and batteries shall allow for possible expansion of the cells during charging.

NOTE 1 For the purpose of this standard, the terms "encapsulate" and "encapsulation" do not imply conformity with IEC 60079-18.

NOTE 2 The physical characteristic of vents will depend upon the type and capacity of the battery arrangements. The effects of ageing on battery capacity and therefore on the rate of gas evolution from the battery must also be considered.

When evaluating battery control arrangements with respect to the potential evolution of gas the full range of operating temperatures, internal resistance and voltage capability shall be considered. It shall be assumed that batteries can become unbalanced but cells with negligible resistance or voltage capability need not be taken into account.

The external surface temperature of the cell or battery shall not exceed the value specified by the cell or battery manufacturer, or 80° C, whichever is the lower.

The electrical connections between cells and to batteries shall comply with 4.2 and shall be of a type recommended by the manufacturer of the cell or battery.

The following clearance and creepage distances shall apply between the cell poles.

- For an inherently safe single cell, that is where the short-circuit current and maximum surface temperature are limited to a suitable value by its internal resistance, the clearance and creepage distances between the cell poles may be ignored.
- For a single cell, with a maximum open-circuit voltage of 2 V or less, not forming part of a battery, the clearance and creepage distances between the cell poles shall be not less than 0,5 mm.
- For batteries where the battery voltage does not exceed 10 V, and both the cells and inter-cell connections are fixed, no additional creepage and clearance distances between the cells are required. The creepage and clearance distances for the external terminals of a battery shall be as given in Table 1.
- For all other batteries and for all cells having a voltage exceeding 2 V, the clearance and creepage distances shall be those appropriate for the voltage, as given in Table 1.

To prevent faulty connection, or the use of cells with different status of charge, or cells of different age, all secondary gas-tight cells shall be securely assembled as a single battery pack.

If cells and batteries do not form an integral part of the apparatus, precautions shall be taken to safeguard against incorrect connection between cells or the battery with the apparatus and charger. Suitable precautions include polarized connectors, or those which are clearly marked to indicate correct assembly. Provision shall also be made for safe interconnection of the circuit.

If electrolyte risks being ejected from cells under normal or one fault conditions, provision shall be made to prevent contamination of live parts. There is no need for protection for sealed gas-tight cells and batteries. Open type or valve regulated cells or batteries shall be enclosed in a separate compartment to avoid electrolyte which may be ejected from the cell causing contamination to other parts of the apparatus. Additionally, for these types of cells or batteries, the creepage and clearance values inside the cell or battery compartment needs to be enhanced to at least 10 mm.

Batteries and their associated safety devices shall be securely mounted, for example held in place by a purpose designed clip or bracket.

There shall be no relative movement between the battery and the associated safety device or devices such as would impair conformity with the requirements of the type protection concerned.

NOTE Conformity with 5.7.2 should be checked before and after the relevant mechanical impact/drop test specified in IEC 60079-0.

Electrical connectors involving heating of the cell (or battery) after manufacture shall not be used except where this is permitted by the cell (or battery) manufacturer.

5.7.3 Release of flammable gas

Cells and batteries are considered to be potential sources of release of flammable gas, and the assumption is made that this may be electrolytic gas, i.e. hydrogen and oxygen in the appropriate proportion resulting from electrolysis. The risk of gas release from cells which are used within limits specified by the cell manufacturer, as well as by the following requirements, is deemed acceptable.

Depending on the different characteristics of the electrochemical systems and the design of cells and batteries, different precautions shall be observed. For this reason, cells and batteries are classified according to the risk of gas, as follows.

a) Cells and batteries which can release gas under normal operating conditions. These types of cells and batteries comprise open cells and sealed valve-regulated cells.

b) Cells and batteries which do not release gas under normal operating conditions. These types of cells and batteries comprise sealed gas-tight cells.

5.7.4 Charging of cells

If the cells and batteries have to be recharged in hazardous areas, the charging circuits shall be fully specified as part of the apparatus. The charging system shall be such that, even with one fault condition on the charging system, the charger voltage and current do not exceed the limits specified by the manufacturer.

No additional requirements apply to the charging of cells which do not release gas under normal operating conditions.

For the charging of cells of a type which release gas under normal operating conditions, the maximum concentration of hydrogen in the battery container shall not exceed 2 % by volume while continuously measured for the duration of the test described in 6.6.4 using the charging apparatus specified as part of the apparatus.

Charging is only permitted within the safety limits specified by the manufacturer.

The manufacturers' instructions may need to include conditions of use, such as prohibiting the transportation of batteries or cells in or into hazardous areas while charging. If the charger is part of the apparatus and does not comply with one of the types of protection listed in IEC 60079-0, it will need to be de-energized and protected from reverse current caused by the cell or battery. If a time shall be specified after which the temperature is below the limit temperature, this time has to be reached before the apparatus with the charger may be transported into the hazardous area.

Where there is another voltage source in the same enclosure, the battery and its associated circuits shall be protected against charging by other than the circuit specifically designed to do so. For example, this may be achieved by separating the battery and its associated circuits from all other voltage source(s) inside the enclosure using the creepage and clearance distances specified in Table 1 for the highest voltage encountered.

5.7.5 Discharge of cells

Where a load current drawn from the battery can cause such damage to the battery as to affect the increased safety properties, the load or safety device shall be specified by the apparatus manufacturer. Where the increased safety properties are not affected, the load need not be specified or safety device provided.

For sealed gas-tight cells, protection against deep discharge and individual cell polarity reversal shall be provided.

Where more than three sealed (gas-tight) cells are connected in series, precautions shall be made against reverse polarity charging of the cells.

NOTE 1 The actual capacity of cells may fade during their working life. If this occurs, cells of higher capacity may force cells of lower capacity into reverse polarity.

Where a deep discharge protection circuit is installed to prevent reverse polarity charging of cells during discharge, the minimum cut-off voltage shall be that specified by the cell or battery manufacturer. The current in amperes from the battery after switching off the load shall be less than 1/1 000 A of the rated capacity.

NOTE 2 If too many cells are connected in series, there may be no safe protection due to tolerances of individual cell voltages and a deep discharge protection circuit. Generally, no more than six cells (in series) should be protected by one deep discharge protection circuit.

For verification and tests of the maximum surface temperature rating, the highest discharge current permitted by the maximum load specified by the apparatus manufacturer or by the protection device shall be taken into account, for example 1,7 × rating of the fuse, or at short-circuit if neither load nor protection device is specified.

The safety devices required by this standard form safety related parts of a control system. It is the responsibility of the manufacturer to assess that the safety integrity of the control system is consistent with the level of safety required by this standard.

NOTE 3 Safety related parts meeting the requirements of category 3 of EN 954-1 would satisfy the above.

5.7.6 Incorporation of other types of protection

For open-type, valve-regulated and also sealed gas-tight cells without safety devices, compartments can include types of protection "e" and "m" apparatus and/or components but not types of protection "d" or "i" apparatus and/or components

5.7.7 Disconnection and transportation

If the battery has to be disconnected from its associated equipment in the hazardous area then it shall be capable of being isolated safely.

Unless the live parts are protected to at least IP30, the cells and batteries shall be marked as shown in item e) of Table 12 to warn that they must not be taken though the hazardous area.

5.8 General purpose connection and junction boxes

General purpose connection and junction boxes shall be allocated a rating determined by the method in 6.7 to ensure that the limiting temperature of 4.7 is not exceeded in service.

The rating (see Annex E) shall be expressed as either

a) the rated maximum dissipated power, or

b) the set of values comprising, for each terminal size, the permissible number and size of conductor and the maximum current.

Information on the use of the rating in determining safe combinations of terminals and conductor for particular values of current is given in Annex E.

5.9 Resistance heaters (other than trace heaters)

5.9.1 This subclause specifies supplementary requirements for the resistance heating devices and resistance heating units (other than trace heaters) defined in 3.12. It does not apply to induction heating, skin effect heating, dielectric heating or to any other heating system which involves passing current through a liquid, an enclosure or pipework.

NOTE 1 The requirements for trace heaters are given in IEC 62086-1.

NOTE 2 Additional measures of safety for increased safety have been applied to resistance heating by a mandated temperature limit device, sealed containment, residual current detection (30 mA – 300 mA) with an acceptable grounded housing or an insulation monitoring system, and thermal stability tests of the insulation system.

5.9.2 For the purpose of this subclause:

- heating resistors are not considered to be windings and 4.6 does not apply;
- Clause 7 of IEC 60079-0 does not apply to the electrical insulating materials of heating resistors.

5.9.3 The heating resistor shall have a positive temperature coefficient. The manufacturer shall specify the value of the resistance at 20 °C and its tolerance.

5.9.4 The insulating materials used in a resistance heating device shall be tested in accordance with 6.8.4.

5.9.5 The cold start current of the resistance heating device when tested in accordance with 6.8.6 shall not exceed the manufacturer's declared value by more than 10 % at any time after the first 10 s of energization.

5.9.6 The manufacturer shall specify an electrical protective device for use with each resistance heating device or unit. Unless the resistance heating device or unit is intended to be mechanically protected by the manner in which it is incorporated in an electrical apparatus, (for example an anti-condensation heater in an electric motor), the protective device shall comply with the requirements in Annex D.

5.9.7 When an electrically conductive covering ensures the function of the protective device foreseen in 5.9.6, it shall extend over the whole of the surface of the insulating sheath and consist of an evenly distributed conductive layer with a coverage of at least 70 % of the insulating surface. The electrical resistance of the conductive covering shall be sufficient to ensure operation of the protective device foreseen in 5.9.6.

5.9.8 The electrical insulation shall ensure that the heating resistors cannot be in contact with the potentially explosive atmosphere, unless the surface temperature is below the limiting temperature.

NOTE Beaded insulation for instance would not satisfy this requirement

5.9.9 The cross-section of the conductors for connections to the resistance heating device shall be at least 1 mm^2 for mechanical reasons.

5.9.10 For the determination of the temperature class of a resistance heating device, any additional thermal insulation intended to be installed shall not normally be considered as excluding access of the potentially explosive atmosphere.

5.9.11 The resistance heating device or unit shall be prevented from exceeding the limiting temperature when energized.

This shall be ensured by one of the following means:

a) a stabilized design using the temperature self-limiting characteristic of the resistance heating device;

b) a stabilized design of a heating system (under specified conditions of use),

c) a safety device according to 5.9.12 which, at a pre-determined surface temperature, isolates all live parts of the resistance heating device or unit. This safety device shall be entirely independent of any control system provided for the purpose of regulating the functional temperature of the resistance heating device or unit under normal conditions

For b) and c), the temperature of a resistance heating device is dependent on the relationships between various parameters:

- its heat output;
- the temperature of its surroundings: gas, liquid, workpiece;
- the heat transfer characteristics between the resistance heating device and its surroundings.

The necessary data regarding these relationships shall be provided by the manufacturer in the descriptive documents foreseen by IEC 60079-0.

5.9.12 The protection offered by a safety device shall be achieved.

- by sensing the temperature of the resistance heating device or, if appropriate, of its immediate surroundings; or
- by sensing the surrounding temperature and one or more other parameters; or
- by sensing two or more parameters other than the temperature.

NOTE 1 Examples of such parameters include: level, flow, current and power consumption

Where special conditions for safe use are necessary, appropriate instructions shall be given (see also item i) of 29.2 of IEC 60079-0). For example, when the resistance heating unit is supplied with an incomplete safety device, all the data for handling the signal (such as the compatibility between the transmitter and the receiver, etc.) shall be indicated in the descriptive documents.

The safety device shall de-energize the resistance heating device or unit either directly or indirectly. A reset shall only be possible by hand after the previously defined process conditions have returned, except when the information from the safety device is continuously monitored. In the event of failure of the sensor, the heating device shall be de-energized before the limiting temperature is reached. Resetting or replacement of a manually re-armed safety device shall be possible only with the aid of a tool.

The adjustment of the protective devices shall be locked and sealed and shall not be capable of being subsequently altered when in service.

NOTE 2 Thermal fuses should be replaced only by parts specified by the manufacturer.

The safety device shall operate under abnormal conditions and shall be additional to and functionally independent of any regulating device which may be necessary for operational reasons under the normal conditions.

5.9.13 Resistance heating devices and units shall comply with the requirements for type verifications and tests in 6.8 and for routine verifications and tests in Clause 7.

5.10 Other electrical apparatus

Electrical apparatus or design variants that are not specifically defined in 5.2 to 5.9 shall comply with the constructional requirements in Clause 4 and the principles of the supplementary requirements in Clause 5.

NOTE Equipment constructed to the requirements of this standard is designed to have a "high" level of protection (Gb) and not be a source of ignition in normal operation or when subject to faults that may be expected, though not necessarily on a regular basis. Equipment in accordance with this standard will usually be based on normal industrial product technology which, with temperature limitation, is not a source of ignition in normal service. This subclause is intended to provide opportunities for the incorporation of new technology. The manufacturer should conduct an analysis of potential faults of the equipment to ensure the required degree of safety during operation over the foreseeable life. This should be based on equivalence to those increased degrees of safety achieved over normal industrial equipment as specified in this standard.

6 Type verifications and type tests

These requirements supplement those type tests of IEC 60079-0 which are applicable also, unless otherwise stated, to type of protection increased safety "e".

6.1 Dielectric strength

Dielectric strength shall be verified by a test:

a) either as given in a specific product standard for the individual items of electrical apparatus or, if no such test requirement exists,

b) at the test voltage according to 1), 2) or 3) below, and maintained for at least 1 min without dielectric breakdown occurring.

   1) For electrical apparatus with rated voltages not exceeding 90 V peak or in which working voltages not exceeding 90 V peak are present: 500 V r.m.s. $^{+5}_{0}$ %.

   2) For resistance heating devices and resistance heating units to which additional requirements of 5.9 apply: $(1\,000 + 2U_n)$ V r.m.s. $^{+5}_{0}$ %, where U_n is the rated voltage.

3) For other apparatus and Ex Components, where working voltages in excess of 90 V peak are present: (1 000 + 2U) V r.m.s $^{+5}_{0}$ % or 1 500 V r.m.s $^{+5}_{0}$ %, whichever is greater, where U is the working voltage.

DC test voltages are permitted as an alternative to the specified a.c. test voltage and shall be 170 % of the specified a.c. r.m.s. test voltage for insulated windings, or 140 % of the specified a.c. r.m.s. test voltage for situations where air or creepage distance is the insulating medium.

For apparatus or Ex Components with galvanically isolated parts, the test shall be applied separately, at the appropriate voltage, to each part.

6.2 Rotating electrical machines

6.2.1 Machines with cage rotors shall be subjected to tests with their rotors locked in order to determine the starting current ratio I_A/I_N and the time t_E.

Alternatively, where it is not practical to make tests on a machine, calculated figures for the temperature rise in rated service and stalled conditions along with time t_E may be determined. It is preferred that the calculation method be used only to supplement the test method. See the bibliography for references concerning the calculation of locked-rotor temperature.

The methods of test and of calculation are given in Annex A.

6.2.2 Provided that the test conditions are equivalent to the service conditions, rotating electrical machines may be tested with the axis only in the horizontal position, even if they are intended for use with it in other positions.

6.2.3 Additional tests for machines

6.2.3.1 Stator winding insulation system

6.2.3.1.1 The tests shall be carried out on one of the following test samples:

- one complete stator,
- one stator with motor enclosure,
- one motor,
- a partially wound stator.

In all cases, the test sample shall be in "as new" condition and shall be representative of a complete stator with, where appropriate, corona shield, stress grading, packing and bracing, impregnation and conductive parts such as the stator core. All exposed conductive parts shall be earthed.

6.2.3.1.2 Typical stator connection cables arrangements shall be tested either on one complete stator or in a representative model. Particular care shall be taken with the spacing of the cables, both from each other and from adjacent conductive parts. All such exposed conductive parts shall be earthed.

6.2.3.1.3 Insulation systems and connection cables shall be tested in an explosive test mixture as shown in Table 8 with a sinusoidal voltage of at least 1,5 times the rated r.m.s. line voltage for at least 3 min. The maximum rate of voltage rise shall be 0,5 kV/s. The voltage shall be applied between one phase and earth with the other phases earthed.

No ignition of the explosive test mixture shall occur.

Table 8 – Explosion test mixtures

Apparatus group	Test mixture in air v/v
IIC	(21 ± 5) % hydrogen
IIB	(7,8 ± 1) % ethylene
IIA	(5,25 ± 0,5) % propane

6.2.3.1.4 Insulation systems and connecting cables shall be tested in an explosive test mixture as shown in Table 8. They shall be subjected to 10 voltage impulses of not less than three times peak phase to earth voltage and with a voltage rise time between 0,2 µs and 0,5 µs, and with a time to half value which is at least 20 µs. The impulses shall be applied phase-to-phase and separately phase-to-earth.

NOTE 1 This is a non-standard waveform but it is believed that it is necessary to use as short a rise time as can practically be achieved to initiate discharge with a sufficient length to contain enough energy for ignition. This is based on the results of experiments conducted by Physikalisch-Technische Bundesanstalt (PTB), in Germany.

NOTE 2 This test is representative of wye (star) connected motors with the supply midpoint earthed or delta connected motors with the virtual midpoint near system earth. Other supply connections would need to be the subject of discussions between the manufacturer and the user to determine suitable insulation system tests.

No ignition of the explosive test mixture shall occur.

6.2.3.2 Cage rotor

6.2.3.2.1 The test shall be carried out using a machine which has a stator and rotor that are representative of a finished machine in terms of the stator core and windings, and the rotor core and cage. This shall include ducts, centring rings, rings under the end rings and balance discs, where appropriate.

6.2.3.2.2 The rotor cage shall be subject to an ageing process comprising a minimum of five locked rotor tests. The maximum temperature of the cage shall cycle between the maximum design temperature and less than 70 °C. The applied voltage shall be not less than 50 % of the rated voltage.

6.2.3.2.3 After the ageing process of 6.2.3.2.2, the machine shall be filled with, or immersed in, an explosive test mixture as shown in Table 8. Motors shall be subjected to 10 direct-on-line uncoupled starts or 10 locked rotor tests. These tests shall have a duration of at least 1 s.

No ignition of the explosive test mixture shall occur.

6.2.3.2.4 During the tests, the terminal voltage shall not fall below 90 % of the rated voltage. The concentration of the explosive test mixture shall be confirmed after each test.

6.3 Luminaires designed for mains supply

6.3.1 Mechanical tests for screw lampholders other than E10

For type E14, E27 and E40 lampholders, a test lamp cap in accordance with the dimensions specified in IEC 60238 shall be fully inserted into the lampholder, applying an insertion torque as prescribed in Table 9. For type E13, E26, and E39 lampholders, an equivalent test shall be performed based on the dimensional requirements of IEC 60238, modified for differences between related lamp caps given in IEC 60061-2.

The test lamp cap shall then be partly withdrawn by rotating through at least 15° and the torque then required to remove the cap shall be not less than the minimum removal torque prescribed in Table 9.

Table 9 – Insertion torque and minimum removal torque

Lamp cap size	Insertion torque Nm	Minimum removal torque Nm
E14 / E13	1.0 ± 0.1	0.3
E27 / E26	1.5 ± 0.1	0.5
E40 / E39	3.0 ± 0.1	1 0

6.3.2 Abnormal operation of luminaires with tubular fluorescent lamps

6.3.2.1 Rectification test

The luminaire is supplied at a voltage of 110 % of its rated voltage and a diode is then introduced in series with the lamp. When temperatures have stabilized, the temperature shall not have exceeded that given in IEC 60079-0 for the temperature class.

With the diode in circuit, the luminaire is then supplied at rated voltage and when temperatures have stabilized, the limiting temperature given in 1 b) of Table 3 shall not be exceeded.

NOTE It may be necessary to introduce the diode into the lamp circuit after the arc is initiated.

6.3.2.2 Inoperative lamp test

The luminaire is supplied at a voltage of 110 % of its rated voltage and lamps are removed as necessary to cover all possible combinations. When temperatures have stabilized, the temperature shall not have exceeded that given in IEC 60079-0 for the temperature class.

The luminaire is supplied at a voltage of 110 % of its rated voltage and lamps are removed as necessary to cover all possible combinations and, when temperatures have stabilized, the limiting temperature given in 1 b) of Table 3 shall not be exceeded.

6.3.2.3 Power dissipation of cathodes of lamps supplied by electronic ballasts

The asymmetric pulse test and the asymmetric power dissipation test according to Annex H shall be conducted. For T8, T10, and T12 lamps, the maximum cathode power observed during the tests shall not exceed 10 W.

The values for the maximum cathode power of size T4 (12 mm) and T5 (16 mm) lamps in increased safety luminaires is under consideration.

NOTE The limits for the power dissipation in cathodes of lamps supplied by electronic ballasts limits were derived from experimental data on luminaires operated in an ambient temperature of 60 °C and with a temperature class of T4

6.3.3 Sulphur dioxide test for the connection of bi-pin lamp caps to lampholders

The connections shall be tested according to IEC 60068-2-42 for a period of 21 days with the contacts fully assembled.

After the test, the contact resistance shall not have increased by more than 50 % of the initial value.

Representative lamp cap pins shall be made of brass with a minimum 0,8 µm finish, and chemically brightened. The pins and their arrangement shall conform to the dimensional requirements given in IEC 60400.

6.3.4 Vibration test for luminaires with bi-pin lamps

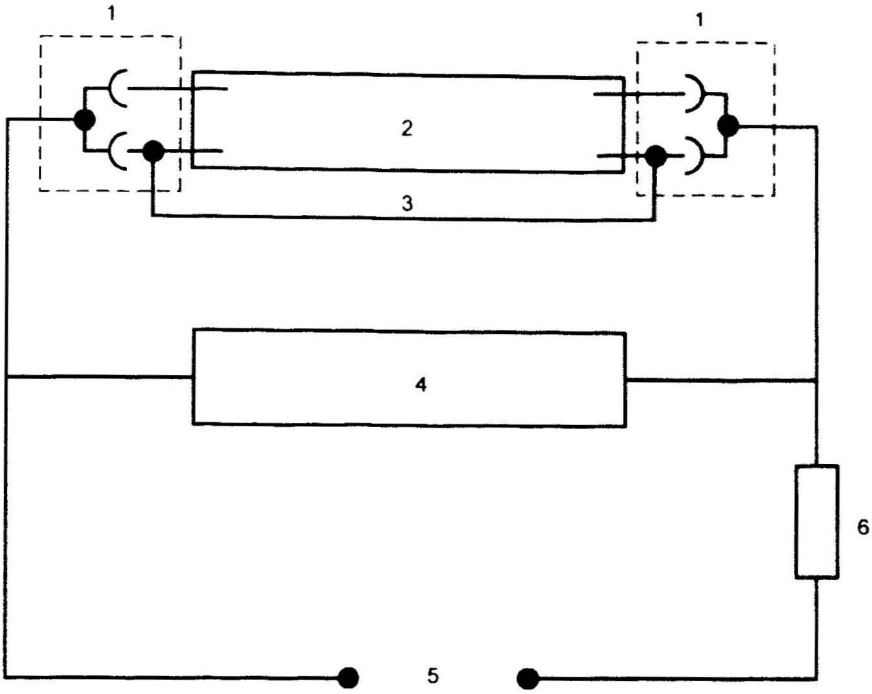
The luminaires shall be submitted to a vibration endurance test according to IEC 60068-2-6.

A complete sample of the luminaire is mounted by its normal fixings to a rigid test fixture, and exposed to frequencies between 1 Hz and 100 Hz.

Between 1 Hz and 9 Hz, the amplitude shall be 1,5 mm; between 9 Hz and 100 Hz, the test unit shall be subjected to an acceleration of 0,5 g.

The frequency sweep rate shall be 1 octave per minute with an endurance exposure of 20 cycles in each of the orthogonal planes.

After the exposure, there shall be no visible mechanical damage on all parts of the luminaire. Furthermore, current shall be passed through the lamp contacts, in series using a d.c. supply as shown in Figure 3. If the lampholder contacts are mechanically asymmetrical, the test shall be repeated with the active contacts reversed.



Key

1	lampholder	4	oscilloscope
2	lamp	5	24 V d.c.
3	connection	6	resistor

Figure 3 – Arrangement for the luminaire vibration test

A special test lamp is prepared by disrupting the cathodes using a high current and a lightweight connection made across the lamp.

The current during the test shall be the rated r.m.s. value for the lamp.

During the test, no evidence of current interruption or change in contact voltage shall be observed.

6.4 Measuring instruments and instrument transformers

The temperature rise of current transformers with their secondary windings short-circuited and of the current-carrying parts of measuring instruments when the current I_{th} flows for 1 s may be established by calculation or test. In making these calculations, the temperature coefficient of resistance shall be taken into account but heat losses shall be ignored.

The dynamic strength of current-carrying parts shall be verified by testing. Current transformers shall be subjected to the test with their secondary windings short-circuited. The duration of the dynamic test shall be at least 0,01 s with a primary current peak value not less than I_{dyn} for at least one peak.

The duration of the thermal test shall be at least 1 s with an r.m.s. value of primary current not less than I_{th}.

The dynamic test may be combined with the thermal test provided that

- the first major peak current of the test is not less than the dynamic current (I_{dyn}), and
- the test is made at a current I for a time t so that (I^2t) is not numerically less than (I_{th})^2 and provided t has a value between 0,5 s and 5 s.

An inter-turn overvoltage test shall be carried out on current transformers by the method given in IEC 60044-6 but with an r.m.s. value of primary current equal to 1,2 times the rated value of primary current.

6.5 Transformers other than instrument transformers

The temperature rise of transformers shall be determined by test while connected to the specified load. Any integral or fully-specified protective device shall be in circuit.

Additionally, if the specified load does not form part of the apparatus for which compliance with this standard is claimed, the transformer shall be tested under the most adverse load conditions, including short-circuit of secondary windings. Any integral or fully-specified protective device shall be in circuit.

6.6 Secondary batteries

6.6.1 Application of tests

These type tests are applied to batteries to which the additional requirements of 5.7 apply.

6.6.2 Insulation resistance

6.6.2.1 Test conditions are as follows:

a) the measuring voltage of the ohmmeter shall be at least 100 V;

b) all connections between the battery and the external circuits and, where fitted, the battery container shall be disconnected;

c) the cells shall be filled with electrolyte up to the maximum permissible level.

6.6.2.2 The insulation resistance is considered satisfactory if the measured value is equal to at least 1 MΩ.

6.6.3 Shock test

6.6.3.1 General

Batteries which are subject to mechanical shocks in normal service shall be submitted to this test. Other batteries are not to be submitted to this test but their marking shall then include the symbol "X" according to i) of 29.2 of IEC 60079-0, and the special conditions for safe use shall include this restriction.

The test shall be carried out only on samples of cells and their connections. Where cells of similar construction are foreseen in a range of capacities, it is not necessary to test every capacity but only a sufficient number of them to allow assessment of the behaviour of the complete range.

6.6.3.2 Test conditions

A test shall be carried out on each sample, comprising at least 2 × 2 new and fully-charged cells complete with intercell connectors, installed in a suitable container Each sample shall be in ready-for-use condition.

Each sample shall be mounted in its normal operating attitude and by its normal means of attachment, either directly or by means of a rigid fixture, to the mounting surface of the shock machine. The mounting shall satisfy the requirements of 4.3 of IEC 60068-2-27

The shock machine shall generate a half-sine pulse as shown in Figure 2 of IEC 60068-2-27 The velocity change tolerance, transverse motion and measuring system shall satisfy the requirements of 4.1.2, 4.1.3 and 4.2 respectively of IEC 60068-2-27. The peak acceleration value shall be 5 g_n, as defined in Table 1 of IEC 60068-2-27.

6.6.3.3 Test procedure

The test procedure for each sample shall be as follows:

a) the capacity of each sample is determined;

b) a constant discharge current at the 5 h rate flows during the test;

c) 15 independent shocks are applied to each sample as follows:

- three successive shocks in the vertically upwards direction,
- three successive shocks in each direction along two perpendicular axes in the horizontal plane. These axes are chosen so as to reveal possible weaknesses.

d) after recharging, the capacity is again determined.

6.6.3.4 Acceptance criteria

The following three conditions shall be satisfied for each sample:

a) no abrupt change in voltage during the test,

b) no visible damage or deformation,

c) no reduction in capacity of more than 5 %.

6.6.4 Test for ventilation of battery container

6.6.4.1 The purpose of the test is the determination of the maximum hydrogen concentration within the battery container and the adequate dimensioning of its ventilation openings. For this, hydrogen is released within the battery container.

6.6.4.2 The flow rate of hydrogen to be released in the battery container shall be determined by the following formula:

$$\text{Hydrogen (m}^3\text{/h)} = \text{number of cells} \times \text{capacity (Ah)} \times 5 \times 10^{-6}$$

NOTE The formula is valid when pure hydrogen is used When impure hydrogen is used, the flow rate should be sufficiently increased to compensate for the impurity of the hydrogen

6.6.4.3 One of the following methods may be used. The test shall be carried out at atmospheric pressure in an area free from appreciable draughts.

a) Method 1

That part of the battery container which normally contains the cells shall be fitted with closed boxes. The lids of the boxes shall be provided with filler and vent plugs identical in form, number and location with those on the cells. The location of the boxes shall be such that the natural ventilation normally existing between the cells is unchanged.

Into the space above the boxes, hydrogen shall be fed through the filler and vent plugs with a constant flow corresponding to the type of construction of the cells and to their capacity. The volume of hydrogen required shall be determined from the formula given in 6.6.4.2.

The hydrogen shall be distributed equally amongst all the filler and vent plugs.

b) Method 2

The battery container shall be equipped with a battery made up of cells of the number, type and capacity intended to be used in service.

The cells shall be new, fully charged and connected in series.

An overcharging current shall be passed through the battery to produce hydrogen at a constant flow corresponding to the number, size, type of construction and capacity of the cells in the battery.

The volume of hydrogen to be released shall be determined by the formula given in 6.6.4.2. The overcharging current is determined by the following formula:

$$\text{overcharging current} = \frac{\text{hydrogen}}{\text{number of cells} \times 0{,}44 \times 10^{-3}}$$

where overcharging current is in amperes and hydrogen is in cubic meters per hour.

At the beginning of the test, the ambient temperature, the temperature of the battery container and the temperature of the cells or of the boxes simulating the cells shall not differ from each other by more than 4 K. These temperatures shall be between 15 °C and 25 °C.

6.6.4.4 The test shall be continued until four consecutive measurements have shown that the increase in the hydrogen concentration does not exceed the mean of the four measurements by more than 5 %. If the hydrogen concentration decreases in the course of measurement, the maximum measured value shall be considered.

The time interval between consecutive measurements shall be not less than 30 min. If, in the case of continuous measurement, high concentration values are measured for short periods, these may be omitted if the period is less than 30 min.

The measurement of the hydrogen concentration shall be made at different positions beneath the cover in order to locate and measure the highest concentration in the container.

The measurement shall be made approximately central to the upper surface of the cells (or closed boxes) and the cover of the battery container and at a distance from the filler and vent plugs.

6.6.4.5 The test shall be carried out at least twice.

6.6.4.6 The test is satisfactory if the hydrogen concentration thus determined does not exceed 2 %.

6.7 General purpose connection and junction boxes

The general purpose connection or junction box shall be fitted with a number of the "worst case" terminals that are wired using conductors of the maximum size specified for that particular terminal. The length of conductor connected to each terminal and contained within the enclosure shall be equal to the maximum internal dimension (three-dimensional diagonal) of the enclosure. The wiring shall be arranged so that the test current is passed through each terminal and its wiring in series. In order to represent the thermal effects of bunching of conductors and also other effects of typical installations, the conductors shall be arranged in groups of six with a length outside the box of at least 0,5 m.

A current equal to the rated current of the terminal for the application shall be passed through the series circuit. The temperature of the hottest part shall be measured when steady state conditions have been reached. To facilitate the substitution of alternative terminal types in accordance with Annex E, the temperature rise above local ambient (i.e. immediately surrounding the terminal inside the terminal enclosure) shall be determined for the worst case terminal.

If the limiting value of the maximum dissipated power has to be determined for a particular temperature class, then it is necessary to vary the number of terminals and repeat the test until the limiting temperature is approached. The rated maximum dissipated power (see item a) of 5.8 and Annex E) shall be calculated using the circuit resistance at 20 °C and the rated current applied in the test.

NOTE 1 The "worst case" terminal is that which has been found to exhibit the highest temperature rise. Varying the conductor size, conductor entry location, terminal location / geometry, and terminal size has been found to affect the results.

NOTE 2 The rated maximum dissipated power is calculated using the 20 °C resistance value to facilitate the calculation of permissible combinations of terminals, wiring and currents (see Annex E).

6.8 Resistance heating devices and resistance heating units

6.8.1 These type tests apply to resistance heating devices and resistance heating units to which the additional requirements of 5.9 apply.

6.8.2 The tests shall be carried out on a sample or prototype of the resistance heating device.

6.8.3 The verification of the electrical insulation of the sample or prototype shall be by immersion of the relevant part in tap water at temperature between 10 °C and 25 °C for 30 min and then subjecting the sample or prototype to the test in a) followed by that in b):

a) Apply an r.m.s. voltage of $500\ \text{V} + 2U_\text{n}{}^{+5}_{0}\ \%$, where U_n is the rated voltage of the apparatus, for 1 min, with the conductive covering foreseen in 5.9.7 entirely exposed to the water. The voltage is applied between the heating conductor and the conductive covering or, where there is no conductive covering, the water.

   When there are two or more conductors electrically insulated from each other, the voltage is applied between each pair of conductors and then between each conductor and the conductive covering or the water. Connections between conductors, including those under insulation, shall be broken if necessary, for example with parallel heating cable.

b) Measure the insulation resistance with a d.c. source voltage (nominal) of 500 V. The voltage is applied between the heating conductor and the metallic covering, or where there is no metallic covering, the water. The sample or prototype shall have an insulation resistance of at least 20 MΩ.

However, for resistance heating devices comprising cable or tape, having a possible installed length greater than 75 m, the insulation shall have a resistivity not less than 1,5 MΩ·km (for example, 500 MΩ for a 3 m sample).

6.8.4 The thermal stability of the insulating materials of the resistance heating device shall be verified on a sample or prototype by conditioning it in air at a temperature 20 K greater than the maximum operating temperature, but not less than 80 °C, for at least four weeks and subsequently at a temperature between –25 °C and –30 °C for at least 24 h. Compliance of the sample or prototype shall be verified by submitting it to the insulation integrity test of items a) and b) of 6.8.3.

6.8.5 The test for resistance to impact shall be carried out on two new samples or prototypes with an apparatus similar to that shown in IEC 60079-0. An hemispherical hardened steel impact head shall be used with an impact energy according to the degree of mechanical risk as prescribed in that standard, unless the resistance heating device or unit is protected by an enclosure complying with the requirements for enclosures in IEC 60079-0.

6.8.6 The test for the cold start current shall be carried out on three samples or prototypes of the resistance heating device attached either to a thermal mass or to a heat sink in a cold chamber stabilized at the manufacturer's declared cold start temperature ±2 K.

The operating voltage shall be applied to the samples without removing them from the cold environment and a continuous record is made of the current flow obtained during the first minute of energization.

6.8.7 Tests for specific forms of resistance heating devices or units shall be carried out in accordance with Annex B.

6.9 Terminal insulating material tests

A sample terminal shall be mounted as intended in service and shall then be subjected to the thermal endurance tests of IEC 60079-0. At the conclusion of the testing, the terminal shall be maintained at 20 °C ± 5 K for at least 48 h. A copper conductor of the maximum rated size shall then be installed in each connection in accordance with manufacturer's instructions. A pulling force corresponding to the conductor size given in Table 10 shall be applied gradually to each conductor in sequence and maintained at that value for 1 min. The conductor shall not become dislodged from the clamping unit, the terminal assembly shall not separate from the terminal insulator, and the terminal insulator shall not crack.

NOTE Dislodging of the terminal from a mounting rail is not considered a failure. Additional terminals or securing devices may need to be added to the mounting rail to support the terminal and allow the test to be conducted.

Table 10 – Value for pull-out tests

Size of conductor ISO mm^2	Size of conductor AWG	Pull-out force N
0,5	20	20
0,75	18	30
1,0	17	35
1,5	16	40
2,5	14	50
4	12	60
6	10	80
10	8	90
16	6	100
25	4	135
35	2	190
50	0	285
70	00	285
95	000	351
120	250 kcmil	427
150	300 kcmil	441
185	350 kcmil	503
240	500 kcmil	578
300	600 kcmil	578
350	700 kcmil	645
380	750 kcmil	690
400	800 kcmil	690
450	900 kcmil	703
500	1 000 kcmil	779
630	1 250 kcmil	966
750	1 500 kcmil	1 175
890	1 750 kcmil	1 348
1 000	2 000 kcmil	1 522

NOTE 1 Values derived from IEC 60999-1, IEC 60999-2 and IEC 60947-1.

NOTE 2 Annex F gives the comparison between AWG and metric sizes.

7 Routine verifications and routine tests

7.1 Dielectric tests

A dielectric strength test shall be carried out in accordance with 6.1. Alternatively, a test shall be carried out at 1,2 times the test voltage, but maintained for at least 100 ms.

NOTE In some cases, the actual test period could be significantly longer than 100 ms, as a sample with a large distributed capacitance may take longer to reach the actual test voltage.

When the creepage and clearance dimensions are rigidly controlled by tooling in the manufacturing process, the routine tests may be performed on a statistical basis according to ISO 2859-1 with an acceptance quality limit (AQL) of 0,04.

7.2 Dielectric tests for batteries

Contrary to 7.1, the dielectric strength test for batteries shall be carried out in accordance with 6.6.2.

The insulation resistance of a battery is considered satisfactory if the resistance is at least 1 MΩ.

7.3 Inter-turn overvoltage tests

An inter-turn overvoltage test shall be carried out on current transformers by the method given in IEC 60044-6, with an r.m.s. value of primary current equal to the rated value of primary current.

8 Ex component certificates

8.1 General

As the application of increased safety "e" Ex components can often affect temperature rise and creepage/clearance, Ex component certificates shall include the necessary technical information to allow the appropriate evaluation of the application of the Ex component in apparatus.

8.2 Terminals

The schedule of limitations on an Ex component certificate for terminals shall include the following, where applicable:

- details on how the use of qualified terminal jumper accessories may affect the current rating;
- details on how the use of qualified terminal accessories may affect creepage and clearance;
- details on how different mounting options of terminals may affect creepage and clearance;
- details on specific mounting that may be required to provide the required torque resistance;
- details on the number of conductors, if more than one;
- the limiting temperature of the insulation;
- temperature rise when carrying rated current with specified conductor size(s);
- resistance across the terminal with rated conductor cross-section.

9 Marking and instructions

9.1 General marking

These requirements supplement the requirements of IEC 60079-0 which are applicable also to type of protection increased safety "e". The suffix letters A, B, or C shall supplement the marking for group II if the motor explosion tests of 6.2.3 have been conducted.

Electrical apparatus shall be additionally marked with the following:

a) rated voltage and rated current or rated power;

NOTE For apparatus at other than unity power factor, both values should be marked.

b) for rotating electrical machines and, where necessary, for a.c. magnets, the starting current ratio I_A/I_N and time t_E;

c) for measuring instruments with current-carrying parts and for current transformers, the value of short-circuit current I_{SC};

d) for luminaires, the technical data of the lamps to be used, for example, electrical rating and, if necessary, the dimensions;

e) for general purpose connection or junction boxes, the rating expressed as either

  - the rated maximum dissipated power, or
  - the set of values comprising for each terminal size, the permissible number and size of conductor and the maximum current;

f) restrictions in use, for example use in clean environments only;

g) the characteristics of special protective devices where required, for example for temperature control or for arduous starting conditions, and special supply conditions, for example for converters;

h) for batteries in accordance with 5.7:

  - type of construction of cells,
  - number of cells and nominal voltage,
  - rated capacity with the corresponding duration of discharge.

  If no safety measures as foreseen in the note to 5.7.1.1 are applied, then the battery container shall carry the marking per item f) of Table 12;

i) for Ex component terminals:

  - the conductor range,
  - the rated voltage;

  NOTE 1 Where marking space is limited, this information may appear in the instructions

  NOTE 2 As the "e" ratings may be different from the industrial ratings, such ratings should be segregated to the extent possible.

j) for resistance heating devices and resistance heating units to which the additional requirements of 5.9 apply, the operating temperature.

9.2 Instructions for use

9.2.1 Battery operated apparatus

Instructions for use (instructions for maintenance), for display in the battery charging station, shall be supplied with each battery. These shall include all instructions necessary for charging, use and maintenance.

The instructions for use shall include at least the following information:

- the name of the manufacturer or supplier or his registered trade mark,
- the manufacturer's type identification,
- the number of cells and the nominal voltage of the battery,
- the rated capacity with the corresponding duration of discharge,
- the charging instructions,
- any other conditions concerning the safe operation of the battery, for example restrictions on the lifting of the cover during charging, the minimum time before closing the cover because of the release of gas after termination of charging, the checking of the electrolyte level, the specifications for the electrolyte and water for topping up, the mounting position.

Where the battery is not charged in a special charger designed for this application in the specified apparatus, the battery container shall carry the following marking as shown in item g) of Table 12.

9.2.2 Terminals

The instructions for use shall include at least the following information:

- assigned torque values, if the manufacturer assigns a value of tightening torque;
- unless suitable markings are provided, the instructions shall indicate clearly any rearrangement or adjustment that is necessary to adapt to various sizes of conductors, if the rearrangement or adjustment is not obvious;
- instructions for proper installation of the conductor for terminal constructions where the wiring method is not obvious;
- conductor insulation stripping requirements.

9.2.3 Luminaires

The instructions for use shall include at least the following information.

- For bi-pin luminaires, only lamps with brass pins shall be used when installing or replacing lamps.

  NOTE Commercially available lamps normally use brass pins.

- For luminaires using screw-cap lamps, only lamps with insulating material of the lamp cap complying with the requirements for material group I per IEC 60664-1 and with the minimum creepage and clearances shown in Table 11 shall be used when installing or replacing lamps.

Table 11 – Creepage distances and clearances for screw lamp caps

Voltage, *U* V	**Creepage distance and clearance** mm
$U \leq 63$	2
$63 < U \leq 250$	3

NOTE 1 Voltages shown are derived from IEC 60664-1 and are based on the rationalization of supply voltages given in Table 3b IEC 60664-1. When determining the required values for creepage and clearance, the voltage value in the table may be increased by a factor of 1,1 in order to recognize the range of rated voltages in common use.

NOTE 2 The creepage distance and clearance values shown are based on a maximum supply voltage tolerance of ±10 %.

NOTE 3 At 10 V and below, the value of CTI is not relevant and materials not meeting the requirement for material group I may be acceptable.

9.2.4 Motors

Instructions for use (instructions for maintenance) shall be supplied with each motor. The instructions for use shall include at least the following information:

- details for the routine maintenance and lubrication of bearings;
- where applicable, details for the routine testing of insulated rotor bar insulation.

9.3 Warning markings

Where any of the following warning markings are required on the apparatus, the text as described in Table 12, following the word "WARNING", may be replaced by technically equivalent text. Multiple warnings may be combined into one equivalent warning.

Table 12 – Text of warning markings

Item	Reference	WARNING Marking
a)	4.9.3 a)	WARNING – DO NOT OPEN WHEN NON-INTRINSICALLY SAFE CIRCUITS ARE ENERGIZED
b)	4.9.3 b)	WARNING – DO NOT OPEN WHEN ENERGIZED
c)	4.9.3 b)	WARNING – NON-INTRINSICALLY SAFE CIRCUITS PROTECTED BY INTERNAL IP30 COVER
d)	5.7.1.2	WARNING – SEPARATE ONLY IN A NON-HAZARDOUS AREA
e)	5.7.7	WARNING – DO NOT TRANSPORT THROUGH A HAZARDOUS AREA
f)	9.1	WARNING – DO NOT CHARGE IN A HAZARDOUS AREA
g)	9.2.1	WARNING – REFER TO THE INSTRUCTION MANUAL FOR BATTERY CHARGING

Annex A
(normative)

Cage motors – Methods of test and of calculation

A.1 The temperature rises of the stator and rotor which are attained during rated service and the temperature rise occurring in the stalled motor shall be determined.

As far as possible, comparative measurements on similar motors and investigations on models shall be used to check the accuracy of the calculations.

A.2 The temperature rise of the stator and rotor windings at rated service shall be determined in accordance with IEC 60034-1.

A.3 The temperature rise in stalled motors shall be determined experimentally as follows.

A.3.1 With the stalled motor initially at ambient temperature, rated voltage and rated frequency shall be applied.

A.3.2 The stator current measured 5 s after switching on shall be considered to be the starting current I_A.

A.3.3 The temperature rises in the rotor cage (bars and rings) shall be measured by thermocouples and measuring instruments having a time constant that is small compared with the rate of rise of temperature, or by temperature detectors or other means. The highest of the temperatures obtained during these measurements is the one to be considered.

NOTE The temperature rise of individual rotor bars will vary according to their position relative to the space harmonics of the stator winding phase bands. This variation will be at least 20 % for motors with low spatial harmonics but may be significantly greater. In practice, for motors of conventional design, if thermocouples are placed in just two rotor bars 90 electrical degrees apart then an increase of 10 % on the higher measured temperature rise value will allow for any other rotor bar with a high temperature.

A.3.4 The average temperature rise of the stator, determined from resistance measurements, is taken as the temperature rise of the winding.

A.3.5 When the stalled motor test is made with a voltage less than the rated voltage, the measured values shall be increased in proportion to the ratio of those voltages, directly for the starting current (see A.3.2) and according to the square of the temperature rise. Saturation effects, if any, shall be taken into account.

A.4 The temperature rises in stalled motors shall be calculated as follows.

A.4.1 When calculating the temperature of the short-circuited rotor, the temperature rise shall be calculated from the joule heating effect, taking account of the heat generated in the bars and rings as well as of the thermal capacity of the cage. The influence of skin effect on the heat distribution in the bars shall be considered. Allowance may be made for the heat transfer to the iron.

A.4.2 The rate of temperature rise with time, $\Delta\theta/t$, of the stator windings in the stalled motor shall be calculated as follows:

$$\frac{\Delta\theta}{t} = a \times j^2 \times b$$

where

j is the starting current density, in A/mm^2;

a is the coefficient in $\frac{\mathrm{K}}{(\mathrm{A/mm}^2)^2\ \mathrm{s}}$ (for copper, a = 0,006 5);

b = 0,85 (a reduction factor which takes into account the heat dissipation from impregnated windings).

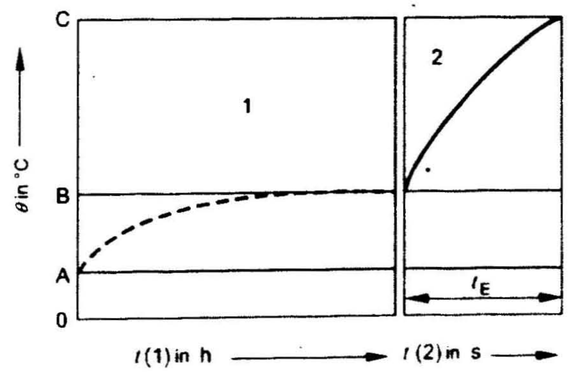
A.5 The time t_E shall be determined as follows (see Figure A.1).

From the limiting temperature C, the maximum ambient temperature A (normally 40 °C) and the temperature rise in rated service AB are subtracted. From this difference BC, and the rate of temperature rise in the stalled motor test (obtained by measurement or calculation), the time t_E is determined.

Separate calculations are made for the rotor and for the stator. The smaller of the two values is taken as the time t_E for the motor, for the appropriate temperature class.

A.6 Motors designed for arduous starting conditions or provided with special protective devices (for example, devices monitoring the temperature of the windings) shall be tested in conjunction with those protective devices.

A.7 Motors forming units with converters and the associated protective devices shall be tested to determine that the relevant limiting temperatures are not exceeded over the range of operating conditions given by the combination of motor and converter.



Key

A highest permissible ambient temperature

B temperature in rated service

C limiting temperature (4.7)

t time

θ temperature

1 temperature rise in rated service

2 temperature rise during stalled rotor test

Figure A.1 – Diagram illustrating the determination of time t_E

Annex B

(normative)

Type tests for specific forms of resistance heating devices or resistance heating units (other than trace heater)

B.1 Resistance heating devices subjected to mechanical stresses

Flexible resistance heating devices not mechanically protected by an enclosure complying with the requirements for enclosures of IEC 60079-0, shall comply with the crush and low temperature bending tests described in IEC 62086-1.

B.2 Resistance heating devices or units intended for immersion

A sample, or part of the sample intended for immersion, is immersed under 50 mm $^{+5}_{0}$ mm of tap water, for 14 days. Compliance is then verified by the insulation integrity test in items a) and b) of 6.8.3.

NOTE This test is not intended to verify the suitability of resistance heating devices or units to operate when immersed in liquids other than water or at pressures of more than 500 Pa.

B.3 Resistance heating devices or units having hygroscopic insulating material

The parts which ensure vapour tightness are subjected to a temperature of (80 ± 2) °C for 4 weeks at not less than 90 % RH After being wiped dry, compliance of the sample is verified by the insulation integrity test in items a) and b) of 6.8.3 but omitting the water immersion.

The descriptive documents according to IEC 60079-0 shall specify the process and the materials to be used to complete the sealing of the resistance heating device or unit.

B.4 Verification of limiting temperature of resistance heating devices (other than trace heaters)

B.4.1 The test shall be carried out according to the procedure of B.4.2, B.4.3 or B.4.4.

B.4.2 Resistance heating unit protected by a safety device in accordance with 5.9.12

The test shall be carried out at the power output of the apparatus corresponding to 10 % overvoltage with any declared minus tolerance on the ohmic resistance.

NOTE Heating units protected by a safety device according to 5.9.12, but tested without the safety device, may be certified as apparatus only if the operating conditions are simulated during the test. Otherwise, the heating unit can only be regarded as an Ex component.

B.4.2.1 Safety device sensing the temperature

The maximum temperature permitted by the safety device shall be determined with any additional regulating devices rendered inoperable. Thermal time constants to ensure stable temperatures shall be taken into account.

B.4.2.2 Safety device sensing the temperature and at least one other parameter

The maximum temperature shall be determined as in B.4.2.1 taking into account the most adverse conditions permitted by the device(s) sensing the other parameter(s).

B.4.2.3 Safety device sensing a parameter other than the temperature

The maximum temperature shall be determined taking into account the most adverse conditions permitted by the devices sensing the other parameter(s)

B.4.3 Resistance heating unit of stabilized design

The sample shall be tested in the worst installation conditions specified by its manufacturer and recognized as such by the testing station. These test conditions shall include, where relevant, zero fluid flow or an empty pipe or vessel. The test is carried out at the power output determined as in B.4.2.

Simulated operating conditions may be utilized.

B.4.4 Heating device with temperature self-limiting characteristic

In the case of a cable or tape, a sample between 3 m and 4 m in length shall be close-coiled inside a close-fitting box of thermally insulating material, capable of withstanding the temperature produced. The box shall be effectively adiabatic. Thermocouples shall be attached to the sample to measure its maximum surface temperature. The sample shall then be energized at 1,1 $U_n\ {}^{+5}_{\ 0}$ % at an initial temperature of (–20 ± 3) °C until thermal equilibrium is reached.

The maximum temperature shall be determined.

Other resistance heating devices with a temperature self-limiting characteristic shall be similarly tested in a suitable effectively adiabatic enclosure.

Annex C
(informative)

Cage motors – Thermal protection in service

C.1 This annex gives additional information for the user as guidance for the selection of protective devices with particular reference to those installation requirements that are different from, or supplementary to, practice in normal industrial installations.

C.2 To satisfy the requirements of 4.7.4 in service, an inverse-time delay overload protective device (for example, a direct-on-line starter with thermal overload relay or release) is acceptable provided that it satisfies the recommendations of Clause C.3.

C.3 Inverse-time delay overload protective devices shall be such that not only is the motor current monitored but also that the stalled motor will be disconnected within the time t_E. The current-time characteristic curves giving the delay time of the overload relay or release as a function of the starting current ratio I_A/I_N should be in the possession of the user.

The curve shall indicate the value of delay time from the cold state related to an ambient temperature of 20 °C and for a range of starting current ratios of at least 3 to 8. The tripping time of the protective devices should be equal to these values of delay time ± 20 %.

C.4 In general, motors for continuous service, involving easy and infrequent starts which do not produce appreciable additional heating, are acceptable with inverse-time delay overload protection. Motors for arduous starting conditions or to be started frequently are acceptable only when suitable protective devices, which ensure that the limiting temperature is not exceeded, are used.

Arduous starting conditions are considered to exist if an inverse-time delay overload protective device, correctly selected according to Clause C.3, disconnects the motor before it reaches its rated speed. Generally, this will happen if the total starting time exceeds 1,7 times t_E.

Annex D
(informative)

Resistance heating devices and units – Additional electrical protection

D.1 Objective

The function of this protection, which is additional to the overcurrent protection, is to limit the heating effect and possible arcing due to abnormal earth fault and earth leakage currents

D.2 Method of protection

This will depend on the type of system earthing (see IEC 60364-5-55 for definitions).

a) **TT and TN systems**

A residual current operated protective device with a rated residual operating current not exceeding 100 mA should be used.

Preference should be given to protective devices with a rated residual operating current of 30 mA. This protective device should have a maximum break time not exceeding 100 ms at the rated residual operating current.

NOTE 1 Typically, this system will disconnect all non-grounded phases at a trip level of 30 mA or higher

NOTE 2 Additional information on residual current protective devices is given in IEC 61008-1

b) **IT system**

An insulation monitoring device should be installed to disconnect the supply whenever the insulation resistance is not greater than 50 Ω/V of rated voltage.

Annex E
(informative)

Combinations of terminals and conductors for general purpose connection and junction boxes

NOTE This annex gives additional information relevant to the two methods of expressing the rating of general purpose connection and junction boxes.

E.1 General

In most types of electrical apparatus, the source of heat is a well-defined part of that apparatus. However, for general purpose connection and junction boxes containing only an array of terminals, the principal source of heat is more likely to be the cables connected to those terminals than the terminals themselves and therefore the actual installation is a critical factor. This fact needs to be recognized in any system of allocating a rating to such general purpose connection and junction boxes for the purpose of allocating a temperature class.

The maximum temperature rise within the enclosure of such a box depends on two factors: the overall population of terminals and wiring within the enclosure, leading to an increased local temperature within the enclosure, the temperature rise of individual terminals and wiring above their own local temperature. The "worst case" terminal referred to in 6.7 is chosen to be a terminal in conjunction with its maximum rated conductor, that exhibits the highest temperature rise above the local temperature. Any terminal can be used with a temperature rise lower than that of the worst case terminal.

E.2 Maximum dissipated power method

The rated maximum dissipated power is determined in accordance with 6.7 using the "worst case" terminal. For an allocated temperature class, the enclosure may be fitted with any number of recognized terminals which may or may not include the "worst case" terminal, up to the maximum number permitted by the physical constraints of the enclosure, provided that the rated maximum dissipated power is not exceeded.

For each terminal, the dissipated power is calculated using the maximum current for that terminal and the value of resistance at 20 °C for the terminal and its associated conductor(s). Each conductor is assumed to have a length from the cable gland to the terminal equal to 0.5 times the maximum internal dimension (three-dimensional diagonal) of the enclosure, that is, the length of the conductor from the cable gland to the terminal is assumed to be one half the length of the terminal to terminal conductor used in 6.7. The sum of these dissipated powers represents the total dissipated power for the configuration and circuit condition. It should not exceed the rated maximum dissipated power.

NOTE To assist in the calculations for an installation, the Ex component certificate for terminal blocks specifies resistance values at 20 °C for terminals.

E.3 Defined arrangement method

As an alternative to specifying the rated maximum dissipated power, it is possible to specify a set of values comprising, for each terminal size, the permissible number of terminals, the conductor size and the maximum current. If more than one combination of values is possible, then the information may be given in the form of a table.

Maximum number of wires in relation to the cross-section and the permissible continuous current.

For an example of defined terminal/conductor arrangement table, see Figure E 1

Current A	**Cross-section in mm^2** 1,5	 2,5	 4	 6	 10										
3	▨	▨	▨	▨											
6	▨	▨	a	▨											
10	40	▨	▨	▨											
16	13	26	▨	▨											
20	5	15	30	▨											
25	▨	7	17	33											
35	▨	▨	3	12											
50	▨	b	▨	▨											
63	▨	▨	▨	▨											
80															
Maximum number of terminals	20	13	15	16											

NOTE 1 All incoming wires and internal links count as wires, earth connections do not count

NOTE 2 When using this table, the simultaneous factor or the rated load factor in accordance with IEC 439 may be taken into consideration. Mixed sizes of terminals with circuits of different cross-sections and currents are possible when the table values are used in the respective proportions.

[a] Any number additionally.

[b] To be engineered by the manufacturer (with heat rise calculation).

Cross-section/mm²	Current/A	Quantity	=	Utilisation
1,5	10	20 (of 40)	=	50 %
2,5	20	3 (of 16)	=	33,3 %
4	25	2 (of 18)	=	11,7 %
		Total < 100 %	=	95,0 %

Figure E.1 – Example of defined terminal/conductor arrangement table

Annex F
(informative)

Dimensions of copper conductors

Table F.1 – Standard cross-sections of copper conductors

Metric size ISO mm²	**Comparison between AWG/kcmil and metric sizes**	
	Size AWG/kcmil	**Equivalent metric area** mm²
0,2	24	0,205
-	22	0,324
0,5	20	0,519
0,75	18	0,82
1	-	-
1,5	16	1,3
2,5	14	2,1
4	12	3,3
6	10	5,3
10	8	8,4
16	6	13,3
25	4	21,2
35	2	33,6
50	0	53,5
70	00	67,4
95	000	85
-	0000	107,2
120	250 kcmil	127
150	300 kcmil	152
185	350 kcmil	177
240	500 kcmil	253
300	600 kcmil	304
350	700 kcmil	355
380	750 kcmil	380
400	800 kcmil	405
450	900 kcmil	456
500	1 000 kcmil	507
630	1 250 kcmil	634
750	1 500 kcmil	760
890	1 750 kcmil	887
1 000	2 000 kcmil	1 014

Annex G
(informative)

Potential stator winding discharge risk assessment – Ignition risk factors

Table G.1 – Potential stator winding discharge risk assessment – Ignition risk factors

Characteristic	Value	Factor
Rated voltage	> 6.6 kV to 11 kV	4
	> 3.3 kV to 6.6 kV	2
	> 1 kV to 3.3 kV	0
Average starting frequency in service	> 1 / hour	3
	> 1 / day	2
	> 1 / week	1
	< 1 / week	0
Time between detailed inspections (see IEC 60079-17, Table 1, type D)	> 10 years	3
	> 5 to 10 years	2
	> 2 to 5 years	1
	< 2 years	0
Degree of protection (IP code)	< IP44 [a]	3
	IP44 and IP54	2
	IP55	1
	> IP55	0
Environmental conditions	Very dirty and wet [b]	4
	Coastal outdoor	3
	Other outdoor	2
	Clean outdoor	1
	Clean and dry indoor	0

[a] Only in clean environments and regularly serviced by trained personnel, see 5.2.1.

[b] "Very dirty and wet" locations include those that may be subjected to deluge systems or comprise open deck on offshore locations.

The ignition risk factor is the sum of the factors for each characteristic. The user should consider the use of the additional measures described in the instructions (see 5.2.7) if the ignition risk factor exceeds 6.

Annex H
(normative)

Test procedure for T8, T10 and T12 lamps

H.1 Asymmetric pulse test

H.1.1 General

The ballast shall have adequate protection to prevent lamp cap overheating at the end of the lamp life. When subjected to the following test, the maximum cathode power shall not exceed 10,0 W.

H.1.2 Test procedure

Refer to the schematic diagram in Figure H.1.

The ballast shall be connected to J2 and the lamp to J4.

a) Close switches S1 and S4, and set switch S2 to position A.

b) Turn on the ballast under test and allow lamp(s) to warm up for 5 min.

c) Close S3, open S1, and wait for 30 s.

d) Measure the sum of the average power dissipated in the power resistors, R1A to R1C and R2A and R2B, and the Zener diodes, D5 to D8.

NOTE This power should be measured as the average value of the product of the voltage between terminals J5 and J6 times the current flowing from J8 to J7. The voltage should be measured with a differential voltage probe, and the current should be measured with a d.c. current probe. A digital oscilloscope can be used for the multiplication and averaging functions. If the ballast operates in a cycling mode, the averaging interval should be set to cover an integer number of cycles (each cycle is typically greater than 1 s.) The sampling rate and number of samples included in the calculations should be sufficient to avoid aliasing errors.

If the measured power is greater than 10,0 W, the ballast has failed and the test is discontinued.

e) If the protection circuit in the ballast has switched off the lamp, then the ballast must be restarted (close S1).

f) Open S4 and S1 and wait for 30 s.

g) As in d), measure the sum of the average power dissipated in the power resistors, R1A to R1C and R2A and R2B, and the Zener diodes, D5 to D8.

If the measured power is greater than 10,0 W, the ballast has failed and the test is discontinued.

h) If the protection circuit in the ballast has switched off the lamp, then the ballast must be restarted (close S1).

i) Close S1 and S4.

j) Set S2 to position B.

k) Repeat steps b) to g).

The ballast shall pass both position "A" and position "B" tests.

l) For multi-lamp ballasts, repeat steps a) to k) for each lamp position. A multi-lamp ballast shall pass the tests for each lamp position.

m) For ballasts that operate multiple lamp types, each lamp type specified shall be tested. Repeat steps a) to l) for each lamp type.

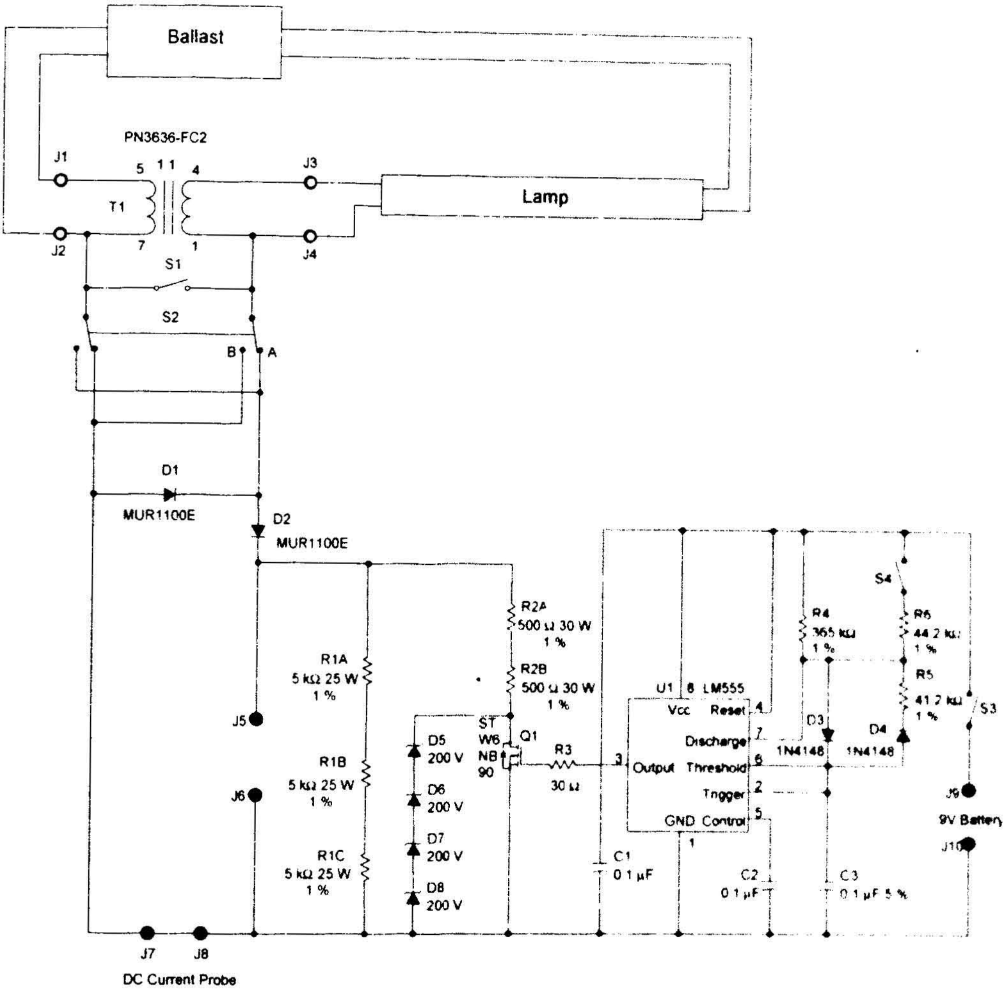


Figure H.1 – Asymmetric pulse test circuit

NOTE FET Q1 should be on for 3 ms and off for 3 ms when S4 is closed, and on for 27 ms and off for 3 ms when S4 is open.

A list of material and transformer specifications is given in Annex K of IEC 61347-2-3. Any other transformer components with the same functionality are permitted.

H.2 Asymmetric power test

H.2.1 General

The ballast shall have adequate protection to prevent lamp cap overheating at the end of the lamp life. When subjected to the following tests, the maximum cathode power shall not exceed 10,0 W with the lamp at a temperature representative of its maximum service temperature.

H.2.2 Test procedure

Refer to the schematic diagram in Figure H.2 and the flowchart of Figure H.3. It is critical that the inductance of resistor R1 be as low as possible (ohmic resistor) due to the high frequency of this circuit.

a) Set switch S1 to position A.

b) Set resistance of resistor R1 to shorted.

c) Start lamp(s) by turning on power to ballast under test and allow lamp(s) to warm up for 5 min.

d) Increase the resistance of R1 rapidly, (within 15 s) until the power dissipated by resistor R1 equals the test wattage value of 20 W (if required making further adjustments to R1 during the first 15 s).

   - If the ballast switches off before reaching the test wattage, or after reaching the test wattage, the ballast must be retested to demonstrate that the maximum possible continuous power, without switching off, is less than or equal to 10 W.
   - Increase the resistance of R1 rapidly (within 15 s) until the power dissipated by resistor R1 equals approximately 5 W.
   - If the ballast fails to turn off in 2 min, stop the test and repeat with an increased resistance in R1.
   - Continue repeating the test with increasing values of R1, approaching a target power dissipation of 10 W (three or four steps is sufficient.).

e) If the ballast fails to switch off within 2 min at a power less than or equal to 10 W, the ballast has failed and the test is discontinued. If the ballast does not switch off in the test of d), but limits the power in R1 to a value less than the test wattage of 20 W, set R1 to the value which produces the maximum wattage.

f) If the 20 W value was reached in step d), wait for an additional 15 s. If the 20 W value was not reached in step d) and the limitation obtained at e) is applicable, wait for an additional 30 s. Then measure the power in resistor R1.

   If the power in resistor R1 has not reduced to 10W or less, the ballast has failed and the test is discontinued.

If the power in resistor R1 is greater than 10,0 W, the ballast has failed and the test is discontinued.

g) Turn off power to ballast. Set switch S1 to position B.

h) Repeat test procedure steps b) to e) above. The ballast shall pass both position "A" and position "B" tests.

i) For multi-lamp ballasts, repeat test procedure steps a) to g) for each lamp position. A multi-lamp ballast shall pass the tests for each lamp position.

j) For ballasts that operate multiple lamp types each lamp type specified shall be tested. Repeat steps a) to h) for each lamp type.

In any of these configurations, if the power in resistor R1 is greater than 10,0 W, the ballast has failed and the test is discontinued.

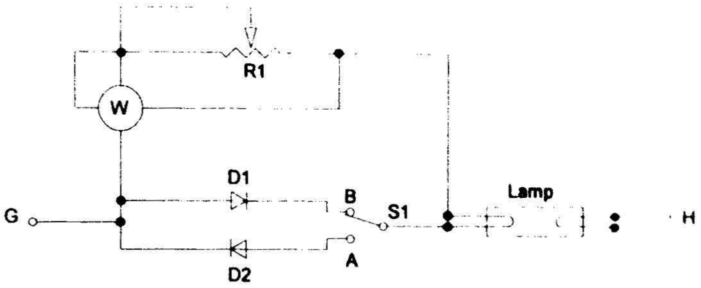


Figure H.2 – Asymmetric power detection circuit

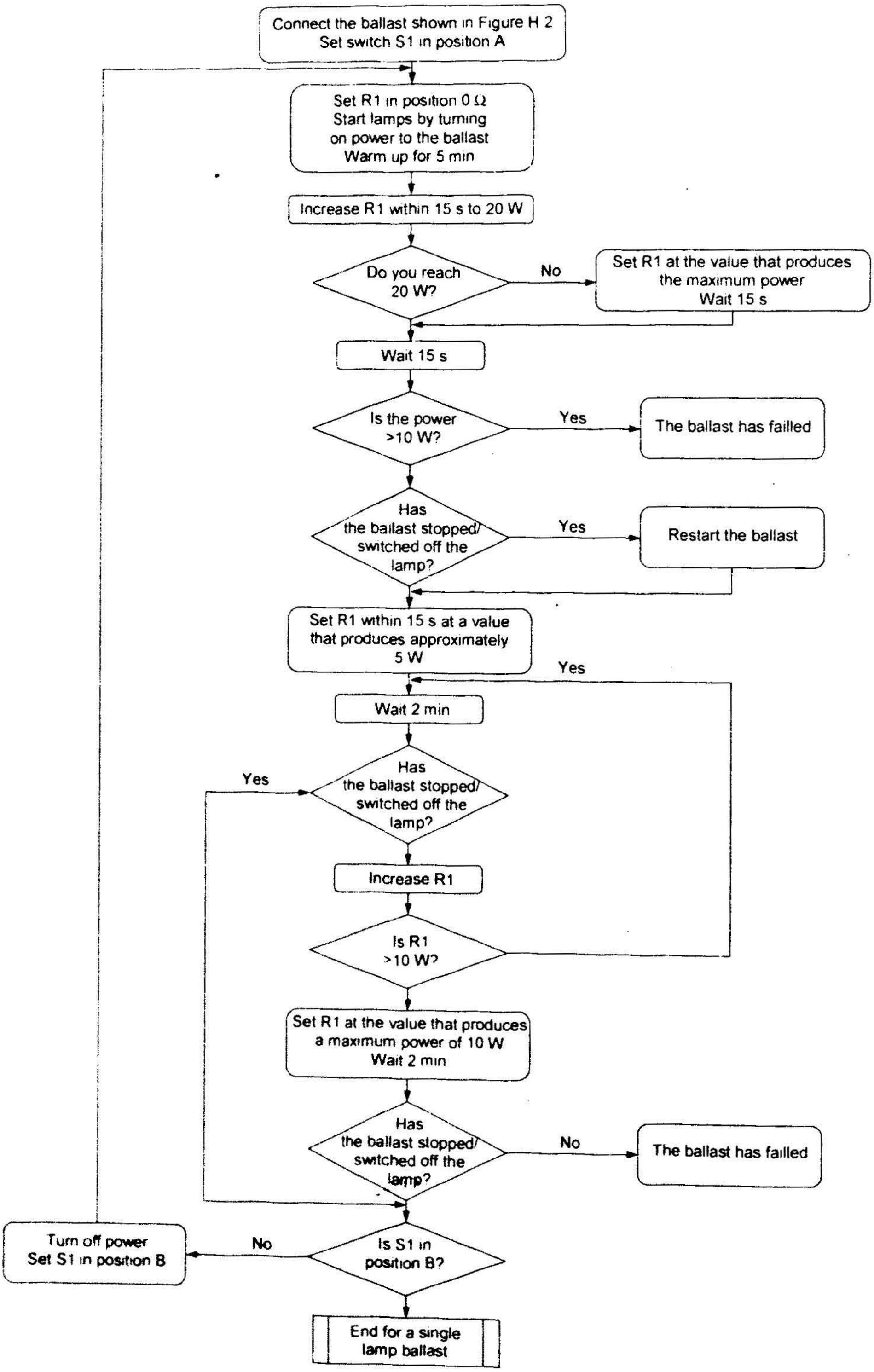


Figure H.3 – Flow Chart – Asymmetric power Test

Annex I
(informative)

Introduction of an alternative risk assessment method encompassing 'Equipment Protection Levels' for Ex Equipment

This annex provides an explanation of the concept of a risk assessment method encompassing Equipment Protection Levels (EPLs). These EPLs are introduced to enable an alternative approach to current methods of selecting Ex equipment.

I.1 Historical Background

Historically, it has been acknowledged that not all types of protection provide the same level of assurance against the possibility of an incendive condition occurring. The Installation Standard, IEC 60079-14, allocates specific types of protection to specific Zones, on the statistical basis that the more likely or frequent the occurrence of an explosive atmosphere, the greater the level of security required against the possibility of an ignition source being active.

Hazardous areas (with the normal exception of coal mining) are divided into zones, according to the degree of hazard. The degree of hazard is defined according to the probability of the occurrence of explosive atmospheres. Generally, no account is taken of the potential consequences of an explosion, nor of other factors such as the toxicity of materials. A true risk assessment would consider all factors.

Acceptance of equipment into each zone is historically based on the type protection. In some cases the type of protection may be divided into different levels of protection which again historically correlate to zones. For example, intrinsic safety is divided into Levels of Protection ia and ib. The Encapsulation 'm' standard includes two levels of protection "ma" and "mb".

In the past, the equipment selection standard has provided a solid link between the type of protection for the equipment and the zone in which the equipment can be used. As noted earlier, nowhere in the IEC system of explosion protection is there any account taken of the potential consequences of an explosion, should it occur.

However, plant operators often make intuitive decisions on extending (or restricting) their Zones in order to compensate for this omission. A typical example is the installation of "Zone 1 Type" navigation equipment in Zone 2 areas of offshore oil production platforms, so that the navigation equipment can remain functional even in the presence of a totally unexpected prolonged gas release. In the other direction, it is reasonable for the owner of a remote, well secured, small pumping station to drive the pump with a "Zone 2 Type" motor, even in Zone 1, if the total amount of gas available to explode is small and the risk to life and property from such an explosion can be discounted.

The situation became more complex with the publication of the first edition of IEC 60079-26 which introduced additional requirements to be applied for equipment intended to be used in Zone 0. Prior to this, Ex ia was considered to be the only technique acceptable in Zone 0.

It has been recognized that it is beneficial to identify and mark all products according to their inherent ignition risk. This would make equipment selection easier and provide the ability to better apply a risk assessment approach, where appropriate.

I.2 Introduction

A risk assessment approach for the acceptance of Ex equipment has been introduced as an ALTERNATIVE method to the current prescriptive and relatively inflexible approach linking equipment to zones. To facilitate this, a system of Equipment Protection Levels has been introduced to clearly indicate the inherent ignition risk of equipment, no matter what type of protection is used.

The system of designating these Equipment Protection Levels is as follows:

I.2.1 Coal Mining (Group I):

I.2.1.1 EPL Ma:

Equipment for installation in a coalmine, having a "very high" level of protection, which has sufficient security that it is unlikely to become an ignition source, even when left energised in the presence of an outbreak of gas.

NOTE Typically communications circuits and gas detection equipment will be constructed to meet the Ma requirements – for example an Ex ia telephone circuit

I.2.1.2 EPL Mb:

Equipment for installation in a coal mine, having a "high" level of protection, which has sufficient security that it is unlikely to become a source of ignition in the time span between there being an outbreak of gas and the equipment being de-energised.

NOTE Typically all the coal winning equipment will be constructed to meet the Mb requirements – for example Ex d motors and switchgear

I.2.2 Gases (Group II):

I.2.2.1 EPL Ga:

Equipment for explosive gas atmospheres, having a "very high" level of protection, which is not a source of ignition in normal operation, expected faults or when subject to rare faults.

I.2.2.2 EPL Gb:

Equipment for explosive gas atmospheres, having a "high" level of protection, which is not a source of ignition in normal operation or when subject to faults that may be expected, though not necessarily on a regular basis.

NOTE The majority of the standard protection concepts bring equipment within this equipment protection level.

I.2.2.3 EPL Gc:

Equipment for explosive gas atmospheres, having a "enhanced" level of protection, which is not a source of ignition in normal operation and which may have some additional protection to ensure that it remains inactive as an ignition source in the case of regular expected occurrences (for example failure of a lamp).

NOTE Typically this will be Ex n equipment.

I.2.3 Dusts (Group III):

I.2.3.1 EPL Da:

Equipment for combustible dust atmospheres, having a "very high" level of protection, which is not a source of ignition in normal operation or when subject to rare faults.

I.2.3.2 EPL Db:

Equipment for combustible dust atmospheres, having a "high" level of protection, which is not a source of ignition in normal operation or when subject to faults that may be expected, though not necessarily on a regular basis.

I.2.3.3 EPL Dc:

Equipment for combustible dust atmospheres, having an "enhanced" level of protection, which is not a source of ignition in normal operation and which may have some additional protection to ensure that it remains inactive as an ignition source in the case of regular expected occurrences.

For the majority of situations, with TYPICAL potential consequences from a resultant explosion, it is intended that the following would apply for use of the equipment in zones (This is not directly applicable for coal mining, as the zone concept does not generally apply):

Table I.1 – Traditional relationship of EPLs to Zones (no additional risk assessment)

Equipment Protection Level	Zone
Ga	0
Gb	1
Gc	2
Da	20
Db	21
Dc	22

I.3 Risk of ignition protection afforded

The various levels of protection of equipment must be capable of functioning in conformity with the operational parameters established by the manufacturer to that level of protection.

Table I.2 – Description of risk of ignition protection provided

Protection afforded	Equipment Protection Level Group	Performance of protection	Conditions of operation
Very High	Ma Group I	Two independent means of protection or safe even when two faults occur independently of each other.	Equipment remains functioning when explosive atmosphere present
Very High	Ga Group II	Two independent means of protection or safe even when two faults occur independently of each other.	Equipment remains functioning in Zones 0,1 and 2
Very High	Da Group III	Two independent means of protection or safe even when two faults occur independently of each other.	Equipment remains functioning in Zones 20, 21 and 22
High	Mb Group I	Suitable for normal operation and severe operating conditions	Equipment de-energised when explosive atmosphere present
High	Gb Group II	Suitable for normal operation and frequently occurring disturbances or equipment where faults are normally taken into account	Equipment remains functioning in Zones 1 and 2
High	Db Group III	Suitable for normal operation and frequently occurring disturbances or equipment where faults are normally taken into account	Equipment remains functioning in Zones 21 and 22
Enhanced	Gc Group II	Suitable for normal operation	Equipment remains functioning in Zone 2
Enhanced	Dc Group III	Suitable for normal operation	Equipment remains functioning in Zone 22

I.4 Implementation

The 4th edition of IEC 60079-14 [encompassing the former requirements of IEC 61241-14] will introduce the EPLs to allow a system of "Risk Assessment" as an alternative method for the selection of equipment. Reference will also be included in the Classification Standards IEC 60079-10 and IEC 61241-10.

The additional marking and the correlation of the existing types of protection are being introduced into the revisions to the following IEC standards:

IEC 60079-0 [encompassing the former requirements of IEC 61241-0]:

IEC 60079-1:

IEC 60079-2 [encompassing the former requirements of IEC 61241-4]:

IEC 60079-5:

IEC 60079-6:

IEC 60079-7:

IEC 60079-11 [encompassing the former requirements of IEC 61241-11];

IEC 60079-15;

IEC 60079-18 [encompassing the former requirements of IEC 61241-18];

IEC 60079-26;

IEC 60079-28;

For the types of protection for explosive gas atmospheres the EPLs require additional marking. For explosive dust atmospheres the present system of marking the zones on equipment is being replaced by marking the EPLs.

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[1] Refer to this paper for discussions of locked-rotor temperature calculations.

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